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COUNTER-TERRORISM TECHNOLOGY ASSESSMENT AND METHODOLOGY STUDY

Research Associates for Defense Conversion, Incorporated

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13. ABSTRACT ***(Maximum 200 Words)***

This is an effort resulting from BAA 98-05, Expert Science and Engineering Program, dated 28 Jan 98. The objective of the effort was to evaluate a variety of technologies that could be applied to Counter-Terrorism including explosives detectors, weapons detection systems, and body cavity contraband systems.

Tasks included identification and coordination with law enforcement agencies to participate in prototype testing, demonstration and evaluation of counter-terrorism technologies, development and implementation of an assessment plan for the prototype testing of counter-terrorism technologies, gathering additional assessment information on counter-terrorism technologies, and recommendations for further development and improvements to counter-terrorism technologies. Data collection and analysis was performed on the RV2000 impulse radar and its effectiveness in Through-the-Wall Surveillance.

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EXECUTIVE SUMMARY

This report discusses the technical efforts conducted under Contract F30602-00-C-0142. These efforts can be grouped into three primary areas: testing of prototype sensors, providing on-site technical and management support to the National Institute of Justice (NIJ), and the modification of a through-the-wall surveillance (TWS) sensor, the radar Flashlight™ for remote operation.

Two sensors were evaluated under the program and a third sensor was demonstrated at a Air Force Research Laboratory (AFRL), Rome Research Site, facility in Rome, NY as discussed in Section 2. The prototype units tested include the Time Domain TWS sensor and the JAYCOR concealed weapon detection (CWD) sensor. The demonstration was performed with a Trex Enterprises CWD sensor.

Tests were conducted on a Time Domain Radar Vision 2000 sensor unit in the spring of 2002 to evaluate its performance in various scenarios. Testing included: evaluation of its ability to penetrate different types of walls, The accuracy of its range readout, and its ability to track various people targets through two types of walls: Gypsum wallboard and 16-inch concrete block.

The attenuation tests yielded two-way attenuation values of 11 dB for an interior Gypsum wall and 18.5 dB for an interior concrete block wall. The sensor was not able to penetrate an exterior brick/concrete block wall. It is unknown whether the exterior wall had a metal vapor barrier or not.

The probability of detection performance using an interior drywall as the intervening medium was approximately 93% with a false alarm rate of 16 per hour. The probability of detection performance using an interior concrete block wall as the intervening medium was approximately 83% with a false alarm rate of 19 per hour. The sensor operator was able to determine the direction that a person was passing 51% of the time for the dry wall medium, but was able to determine the correct direction only 11% of the time for the interior concrete wall. Key comments on the sensor include:

- The sensor packaging and case appears to be reasonably rugged, and withstood our "man-handling" during the test;
- The display was relatively easy to interpret, and after some familiarization, the sensor operator was able to tell the direction of travel of a target;
- The automatic threshold detection mode did not function correctly, but the operation was reliable in the manual threshold mode;
- The weight of the unit was too heavy for a single person to operate unless the sensor was resting on a table;
- The sensor did not detect any targets through 2 types of exterior walls: a brick wall and a 24-inch thick block wall.

10 JAYCOR CWD-2002 acoustic concealed weapon detection sensors were evaluated in the fall of 2002. The evaluations included: physical condition of the units, relative sensitivity, antenna alignment with the laser pointer, and the ability to detect weapons and innocuous items on a human body with and without concealing clothing. Additional tests were performed to estimate the acoustic cross section of weapons and innocuous objects, the attenuation of objects due covering clothing, and the attenuation of the

intervening air. Some of the key characteristics determined for the JAYCOR sensors included:

- The packaging was compact, lightweight, and the controls were easy to operate.
- The batteries were easy to change, and seemed to charge rapidly.
- The units did not travel well. Several were damaged upon receipt.
- The laser pointer was difficult to see in bright sun light. It was reasonably visible on cloudy days.
- There was a significant variability among the 10 unit evaluated both in antenna beam - laser pointer alignment errors and sensitivity.
- Due to the specular nature of the reflections from weapons, they were only visible to the sensor when the geometry was such that the weapon surface was perpendicular to the sensor-weapon line-of-sight. (This tended to occur only when the weapon was located on a person's back, which is more vertical than the sides or front.)
- The reflections from innocuous objects and certain types of clothing such as belts and a denim jacket were larger than those of most weapons.
- No detection of weapons under clothing was observed to occur except for the case of a very thin cotton shirt which was in physical contact with the weapon. (P_D = 0).

The Trex Enterprises sensor was demonstrated at the AFRL, Rome, NY facility in the fall of 2001. Due to the fact that the sensor was a breadboard rather than a prototype, and due to the fact that it was scheduled for other testing on a short schedule, it was decided to perform a demonstration of the sensor rather than a full blown test. A prototype sensor will eventually be available for detailed testing.

Since Research Associates for Defense Conversion, Inc. (RADC) was not in charge of the testing, we were not able to arrange for absolute calibration of the key physical parameter for a radiometer, i.e., the minimum detectable temperature contrast ΔT_{min}. However, the air temperatures were measured, the sky temperatures were estimated, and the temperature contrast between the metal weapons and the subject person's body was calculated to be 25K outdoors and 2.4K indoors. Trex had calculated a ΔT_{min} of 5K for the sensor implying that the weapon should be detectable outdoors, but not indoors. It was observed that the weapons were easily detectable by the sensor outdoors, but were not detectable indoors.

RADC provided an on-site representative at the NIJ Facility in Washington, DC, under this program. The duties included: providing counter-terrorism technology research and assessment; serving as technical point of contact between the Office of Science and Technology of NIJ and the Joint Program Steering Group; performing research into the development of requirements, standards, and testing protocols for counter-terrorism equipment, and assessing techniques for concealed weapons technology. These efforts are discussed in Section 3.

RADC, through a subcontract to the Georgia Tech Research Institute (GTRI) modified the Radar Flashlight™, which is a hand-held device, to provide for remote operation of up to

25 feet with the sensor mounted on a tripod. Control of the tripod and display of the sensor data was provided for in a remote control device. This is discussed in Section 2.

SECTION 1 INTRODUCTION

1.1 Background

This report discusses a program to provide support to the National Institute of Justice (NIJ), the Office of Science and Technology (OST) and the Joint Program steering Group (JPSG) in the following areas: 1) evaluation of prototype concealed weapon detection (CWD) sensors and through-the-wall surveillance (TWS) sensors under development by the NIJ and the Air Force Research Laboratory (AFRL); 2) identify and make recommendations to law enforcement agencies on the usefulness of the above technologies; 3) perform research and development into programs related to and dealing with attacks of weapons of mass destruction.

The prototype sensors to be evaluated were of various types and technologies as shown in Table 1. Some of the sensors have lights indicating the presence of a person or weapon; others provide a track of a person or weapons position; and still others provide an image, either still or video, of a person and weapon.

The time table for evaluation is dependent on the availability of prototype sensors to be tested since each sensor has a different delivery schedule, and many of the sensor contractors have experienced development problems leading to delays in completion of prototypes. During the performance period of this effort, 3 sensors became available for either demonstration or testing, and thus, were evaluated.

Mr. John Stedman of Research Associates for Defense Conversion, Inc. (RADC) served as an on-site point of contact at OST between the NIJ/OST and the National Domestic Preparedness Office (NDPO), the Office of State and Local Domestic Preparedness Support (OSLDPS), the Interagency board (IAB), and various Technical Support Working Group (TSWG) sub-groups. He also provided counter-terrorism technology research and development support in the areas of personal alarm monitors for chemical and biological hazards and escape masks to allow first responders to safely exit a hazardous environment. He also supported the Emergency Preparedness and Incident Command system (EPICS) in the development of a simulation for the training of operations command and control personnel to chemical and biological agents release.

Under a modification to the contract, a task was added involving the modification of the "Radar Flashlight™" that was developed by the Georgia Tech Research Institute (GTRI) to provide for remote operation of the device at up to 25 feet from the sensor. The modifications included: mounting the unit on a tripod, adding a pan and tilt unit to the tripod, and developing a remote control and display unit for the Radar Flashlight™ and the pan and tilt unit. A prototype of the modified sensor hardware and software is a deliverable to AFRL and the NIJ.

TABLE 1. TWS/CWD SENSORS UNDER DEVELOPMENT BY AFRL/NIJ

SENSOR DESIGNATION	CONTRACTOR	TECHNOLOGY	OUTPUT
Concealed Weapons Detection System	AKELA	UHF Wide-Band FMCW Resonance Detection	Amplitude-Frequency Plot (Current) Red/Yellow/Green Light (Future)
Portable MMW Concealed Weapon Detection	Chang Industry	Active, Scanned MMW Imager	MMW Image (Current) Highlighted Weapon (Future)
Passive MMW Imager	Trex Enterprises	Passive Focal Plane Array	MMW Video Imagery
Passive MMW Imager	Lockheed Martin	Passive MMW and IR Focal Plane Arrays	Overlay of IR/MMW Video Imagery
Radar Flashlight	Georgia Tech Research Institute	MMW CW Doppler	Red/Yellow/Green Light
Patrol-Car-Mounted Concealed Weapon Detector	Quantum Magnetics	Passive Magnetic Tensor Tracking	2D Display of Track
Ultrasound sensor	JAYCOR	Hand-Held Acoustic Radar	Red/Yellow Lights
Motion And Ranging System (MARS)	Raytheon	L-band FMCW Bistatic Radar	2 D Display of Track
Impulse radar	Time Domain	Hand-Held Impulse Radar	2 D display of Track

1.2 Goals of the Program

The goals of the program can be summarized as: 1) evaluating available CWD/TWS prototypes and reporting the specific performance parameters that will allow the determination of the usefulness of the sensor and operational context within which the technologies can be employed, 2) providing a point of contact for the NIJ Critical Incidents Program as well as liaison with other counter-terrorism agencies, and 3) implementing the modification of the GTRI Radar Flashlight™ for remote operation. The specific goals are discussed below.

1.2.1 Specific Prototype Evaluation Goals

The prototype evaluation procedures were tailored to the sensor, i.e., if the sensor is a type of radar, radar techniques were used to evaluate the sensor; if the sensor is a radiometer, radiometer techniques were used for evaluation. The following goals were pursued during the prototype tests:

- Prepare test plans for Government review prior to testing;
- Collect data to evaluate the sensor performance.
- Collect data to evaluate the potential of the sensor technology.
- Collect data to provide baseline measures;
- Perform tests to determine how well non-technical operators can utilize the sensors;
- Document the potential uses for the technology for military and law enforcement applications;
- Recommend Further Development and Improvements to technology;
- Identify Critical Technology Needs;
- Identify Ongoing Research and Development Efforts.

The evaluations were hampered by the fact that the sensor electronics were not "opened", which only allowed for external testing. Many of the sensors have no external ports for data capture. In these cases, evaluations of the sensors were performed based on their minimum detectable signal and comparison to standard calibration targets.

1.2.2 Technical Point of Contact for Counter-Terrorism Technologies

The goals of the effort to represent the NIJ/OSD in counter-terrorism efforts with law enforcement agencies and DOD agencies included:

- Provide counter-terrorism technology support to the Joint Program Steering Group (JPSG) of NIJ/OST;
- Serve as JSPG liaison between and technical advisor to the National Domestic Preparedness Office and the Office of State and Local Preparedness Services (OSLDPS);
- Work with the National Institute of Standards and Technology/Office of Law Enforcement Standards (NIST/OLES) in the development of requirements, standards, and testing protocols for counter-terrorism equipment;
- Assess current state-of-the-art design testing procedures and interpret results for CWD using MRI techniques in the area of body cavity detection;
- Provide counter-terrorism technology portfolio research and development management and assessment support relative to state and local first responders.

Mr. John Stedman was located at the OSD headquarters during the contract to perform the above duties at the discretion of the NIJ and OSD.

1.2.3 Modification of GTRI Radar Flashlight™ Sensor

The specific goals of the Radar Flashlight™ modification effort included:

- Provide a mounting bracket so the sensor unit can be mounted on a tripod;
- Procure a pan-tilt unit so the sensor unit can be pointed remotely;
- Provide for a remote control for the pan-tilt unit for distances up to 25 feet;
- Provide a remote display for the sensor unit at distances up to 25 feet.
- Provide additional signal processing to reduce sensor motion artifacts from the sensor output display.

These tasks were performed by a subcontractor, the Georgia Tech Research Institute, in Atlanta, Georgia.

SECTION 2 PROTOTYPE SENSOR EVALUATION

2.1 Overview

Currently the Air Force Research Laboratory (AFRL) in conjunction with the National Institute of Justice (NIJ) is developing a number of sensors that perform concealed weapon (CW) detection and surveillance through exterior and interior building walls. Accordingly, an unbiased evaluation needed to be performed on the various prototype CWD sensors that are under development. When prototypes were delivered to the AFRL Rome Facility, an excellent opportunity opened up for such evaluation. This work was performed on sensors that were delivered to the Government during the time period of this effort.

2.1.1 Approach

Our approach to evaluating prototype sensors has been to compare the performance of the sensor with the expected performance based on physical principles. Whatever the type of sensor, there are specific physical laws that describe the limits of operation. By measuring the physical conditions at the time of testing, the performance of a specific sensor can be evaluated and extrapolated to other scenarios that were not tested. Examples include: the use of calibrated radio frequency (RF) reflectors for active radar systems, the use of temperature-stabilized calibration targets for radiometers, the use of calibrated acoustic reflectors for acoustic sensors, and the measurement of the attenuation of the transmitted energy in air and the reflectivity or irradiance of weapons and other objects of interest. This technique should allow the determination of the amount of improvement that could be expected in sensor performance (i.e. What are the theoretical limits?), and the extrapolation to scenarios not evaluated.

During this program, 3 sensors were either demonstrated or evaluated. The demonstration was conducted by the contractor so our role was strictly to act as observers. For this case we could not perform all the desired calibration measurements, but we were able to collect data for the Government signal processing data base. We conducted the other two evaluations so that we were able to perform all of the desired calibration measurements. Unfortunately, direct data outputs from the two sensors evaluated were not available so no data were collected for the Government signal processing data base. A description of the three sensors evaluated follows below.

2.1.2 Sensors Evaluated or Demonstrated

2.1.2.1 Trex Thermovision™ Radiometric Imager

Trex enterprises, Inc., has developed a radiometric imager using an opto-acoustic Bragg cell to electronically scan a line array of radiometric imagers in one plane as shown in Figure 1. By reducing the number receivers they were able to reduce the gain and sensitivity imbalance problems and obtain excellent images with their 1 m RF aperture. The system was designed initially for battlefield imaging, and worked well when large

metal objects such as armored vehicles were to be detected under the cold sky outdoors. This sensor was modified with an alteration to the lens to allow it to be focused at about 10 m for use in CWD applications. This sensor was demonstrated by Trex personnel at the AFRL, Rome Facility in the Fall of 2001 with RADC personnel observing.

Trex Enterprises is making significant improvements to the original PMMW camera under funding from the US Army and the NIJ. These improvements include: a smaller lighter-weight antenna, lower noise figure receivers using low noise amplifiers (LNAs), increased frequency sweep for better integration gain, and improved digital signal processing. Table 2 gives the salient parameters of the improved sensor. Note that the specified sensitivity of 2K may not be good enough to allow concealed weapon detection indoors, but should be quite adequate for outdoors. The high frame update rate of 17 Hz allows the operator's eye to perform time integration on the image of a weapon as a subject moves and changes aspect which should greatly improve detection.

Figure 1. Trex Enterprises first generation Passive MMW Camera with Bragg cell. [1]

Figure 2 gives an artist's rendering of one possible configuration of the system for CWD applications. It is proposed that the reduction of weight might ultimately allow the system to be hand-held.

TABLE 2. PMMW DEMONSTRATION PROOF-OF-CONCEPT CAMERA [1]

Parameter	Value
Frequency	89 ± 5 GHz
Receiver Type	Direct Detection MMIC on Chip
Receive Array	40 X 26 (80 X 52 Pixels)
Primary Optic Diameter	46 cm
Field-of-View	15 X 10 deg.
Sensitivity	2K
Refresh rate	17 Hz, 30 Display Scan Rate

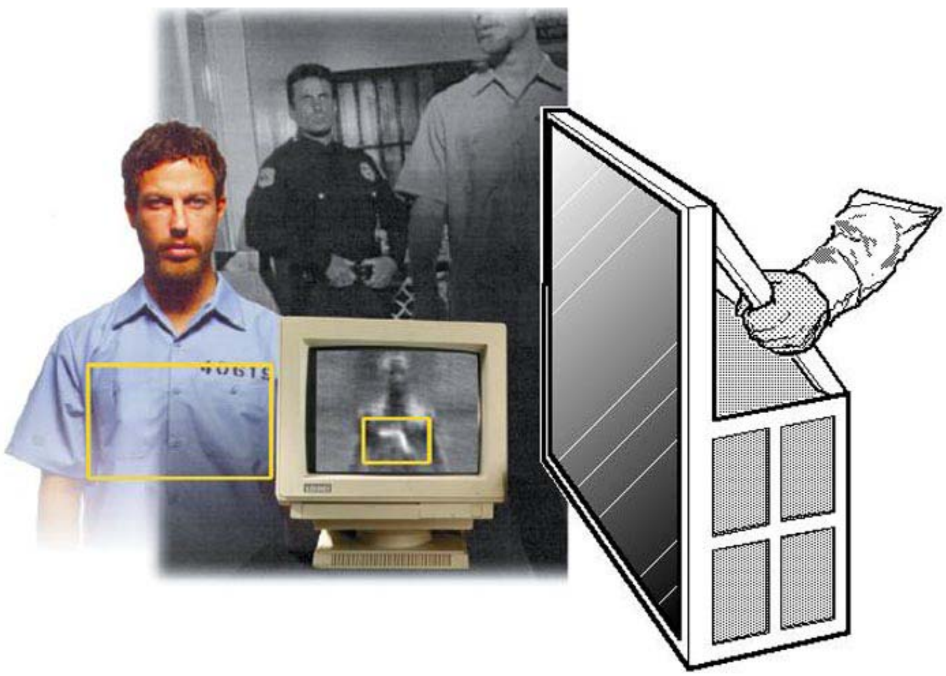

Figure 2. Artist rendering of final system. [1]

2.1.2.2 Time Domain Radar Vision 2000™

Time Domain has developed a technology called "impulse radio" (IR) and their primary application is wireless communications. Basically, an IR system emits ultra-short Gaussian mono-pulses with a tightly controlled pulse-to-pulse time interval. Pulse widths ranging between 0.2 to 1.5 ns (10^{-9} seconds) and interpulse periods of 100 to 1,000 ns. Information and coding are imparted by using pulse position modulation, i.e. the interpulse period is varied between pulses based on an information signal and a channel code. The impulse receiver converts the received RF signal to a base-band digital or analog signal providing a pulse train of varying period. A high speed correlator compares the received base-band signal with a replica of the transmit code yielding the information coding. The information coding can be a digital time signal in which delay

time equals a 0 or a one or an analog signal such as frequency modulation (FM) where (1/interpulse period) equals the frequency.

The key components to the IR system include: an accurate and stable time base, a fast-switching transistor-based transmitter, a wideband compact antenna, a high speed correlator, and suitable pseudo-random codes. Time Domain has developed or licensed each of these technologies for the IR. The transmitter is a fast switching transistor that switches between the "0" and "1" state followed by a filter to generate the monocycle waveform. Time Domain has developed planar wideband antennas with short ring down properties without resistive loading (which increases loss). These antennae exhibit small phase dispersion which results in the short ring times. A 1.9 GHz center frequency antenna measures 2 X 3 X 0.3 inches. An array antenna has been developed consisting of a number of these planar antennas to provide 2-D information. Time Domain has patented an ultra wideband Receiver that correlates a template of the transmit pulse along with the expected time interval with received signal. Working with IBM, they have developed a new integrated circuit using silicon germanium which can measure the very short time delays accurately.

Figure 3 gives a view of the Radar Vision 2000 impulse radar which is intended to detect and track moving persons through a wall or door. At the time of our visit in 1999 the unit was somewhat heavy, i.e. 16 lb., but they were starting the development of large scale integration model to reduce the weight. The newer model is lighter but still unwieldy for a single person. The foot print area is determined by the antenna so could not be reduced significantly. Figure 4 shows the flat panel display of the radar Vision 2000. The display is arranged as a plan, position indicator (PPI) resulting in a "bird's-eye view" of the area being illuminated by the radar with range to a target extending from the bottom center, and the azimuth angle of the target as a rotation around the bottom center which represents the position of the radar.

The specifications for the Radar Vision 2000 were not available to us at the time of the test, but the specifications of the older, Radar Vision 1000 are given in Table 3. The sensor had two modes: standard and high power. In the standard mode, the unit would be mainly useful for looking through thin walls and doors at short range. In the high power mode thicker walls and larger rooms could be searched. The 1999 system could only detect moving targets, but Time Domain was looking into the possibility of being able to detect body motion due to breathing or heartbeats. However, this ability was not demonstrated during our tests.

Figure 3. View of Radar Vision 2000 Sensor.

Figure 4. View of Radar Vision 2000 Display.

TABLE 3. SPECIFICATIONS FOR THE RADAR VISION 1000[2]

CHARACTERISTIC	SPECIFICATION
Center Frequency	2.0 GHz
Bandwidth (3 dB)	1.38 GHz
Range Resolution	< 4 inches
Transmit Power -Standard - High	0.01 mW 1.0 mW
Antenna Gain	6 dBi
Code Span (amt of variation in period)	20 ns
Code Length	128 periods
PRF	5 MHz
Field of View - Az - El	120 deg 100 deg
Minimum Target RCS	< -110 dBsm
Target Velocity Range for Detection	0.5-15 fps
Max Range - Standard - High Power	20 ft 50 ft

2.1.2.3 JAYCOR CWD-2002™ Acoustic Concealed Weapon Detector

The JAYCOR CWD-2002, shown in Figure 5, is a second generation acoustic sensor for CWD applications. The available specifications are listed in Table 4. The unit is designed to be hand-held and pointed at a subject that is suspected of harboring a concealed weapon. A laser aiming light is available to assist in positioning the acoustic beam as well as a speaker or an earphone jack. A trigger switch is depressed which turns on the acoustic transmitter, and the strength of the return is measured by colored light emitting diode (LED) lights as shown in Figure 6.

JAYCOR has not discussed their signal processing techniques, but presumably they count on a rigid object such as a concealed weapon to provide a stronger return than a softer body. Also, presumably, some sort of automatic gain control (AGC) is utilized in order to reduce the range dependence of the return signals. And finally a sweeping range gate probably determines the range of the maximum return which is assumed to be the target. It is not known whether any range or cross range target spatial filters are utilized.

TABLE 4. MODEL CWD-2002 SPECIFICATIONS[3]

Parameter	Values
Transmit Medium/Frequency	Acoustic/40 kHz
Instrumented Range	4-25 ft.
Acoustic Beamwidth	30 degrees 4-12 ft, 2 degrees > 12 ft.
Aiming Mechanism	High Intensity Light or Laser Diode
Display	5-Level Color-Coded LED's
Batteries	Rechargeable Ni-Cad
Battery Life	1 hour Continuous Operation With High Intensity Light 8 hours Continuous Operation With Laser Diode
Weight	3 lbs.

Figure 5. JAYCOR Model CWD-2002 Sensor.[3]

Figure 6. Rear of CWD-2002 showing LEDs.[3]

2.1.2.4 Georgia Tech Research Institute Radar Flashlight™

The Georgia Tech Research Institute (GTRI) developed a MMW radar for use in the 1996 Olympics in Atlanta, Georgia.[4] It was claimed that Olympic class rifle competitors could sense their own heartbeats to the point that they could fire between heartbeats in order to prevent the small deflections in aim caused by a heartbeat. In order to determine the validity of such claims, GTRI developed a system which was a FM CW radar capable of detecting the deflection of a person's skin during a heartbeat. The GTRI design was based on a 1990 patent for a system to determine whether a soldier on a battlefield was alive at a distance. The goal of the GTRI system was to measure heartbeat pulses at 100m.

Figure 7 shows the video output of the system for a test subject at about 4 m from the radar. The large swings in amplitude are due to breathing. The signals are very repeatable.

Following the Olympics, GTRI developed a new heartbeat sensor for use in law enforcement applications dubbed the Radar Flashlight™. The transducer was contained within a housing that resembles a lantern flashlight as shown in Figure 8. The flashlight frequency is at 35 GHz to make up to some extent for the smaller antenna aperture. GTRI has successfully demonstrated the detection of the signature of a person breathing

behind an 8-inch concrete wall. This sensor is the one that was modified under this contract.

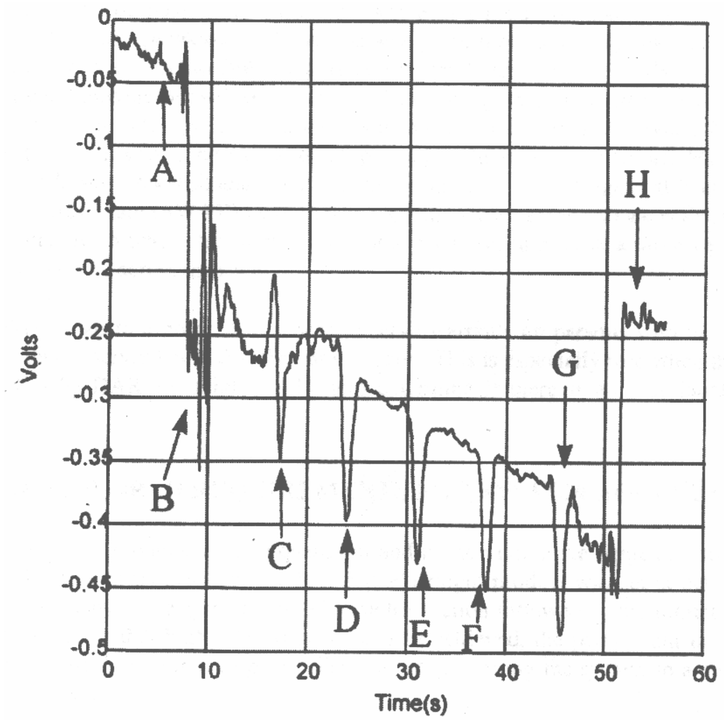

Figure 7. Time recording of breathing collected with radar through interior concrete wall.[4]

Figure 8. Portable version of the GTRI Radar Flashlight™ sensor.[5]

2.2 Test Planning

2.2.1 Overview

This section discusses the planning activities conducted for the tests that were performed as a part of the prototype sensor evaluations. The goals of the planning exercise consisted of the following:

- Determining the site and schedule for the testing;
- Determining the resources that would be required for the tests, i.e., what was available and what would have to be procured or constructed;
- Describing the sensor to be tested;
- Establishing a theoretical basis for the sensor performance as a baseline for comparison;
- Defining the key test variables;
- Developing a preliminary test matrix;
- Summarizing the expected results.

These key planning elements are discussed below.

2.2.2 Approach

2.2.2.1 Test Site and Schedule

Primary consideration in determining the test site and schedule:

- The initial location of the sensor;
- The size and weight of the sensor;
- The amount of contractor support needed to keep the sensor operating normally;
- The location of special equipment or facilities needed to perform the tests;
- The amount of time the sensor is available for testing;
- The location of test personnel.

All of the above considerations were taken into account during the demonstration and the two evaluation tests performed under the contract.

2.2.2.2 Required Resources

As example of the resources required for a test and effect on test site, consider the Time Domain prototype sensor test.[6] The test beds required for the detection performance measurements included: 1) an open area with 100 ft or more of range and the availability of different types of walls through which to view the open area, 2) a large room with an adjacent office where the sensor can be placed next to the wall into the large room. The sensor must be emplaced next to the wall in such a way that the display can be monitored. A door is required to allow entry into the large room without the knowledge of the person monitoring the sensor in the adjacent office. Since tests may occur over several days, it

must be feasible to leave the sensor in place overnight between test periods. Also, the sensor was stored in a large room in Building 106 at the AFRL Rome Facility. Thus, the decision was made to test the Time Domain sensor at AFRL, Rome. However, only one type of wall was available in Building 106, so The Stiefvater Consultants facility near the AFRL, Rome, facility was also used as a test bed.

Due to the relatively low frequencies of the Time Domain sensor, calibration targets could be easily produced by covering rubber balls with aluminum foil.

2.2.3 Sensor Description

In each test plan the best information available on the prototype sensor to be evaluated was obtained and included in the test plan. This information was used both to assist in the development of the test procedures and to provide the reader of the plan and feel for the sensor to be tested.

2.2.4 Establishing a Theoretical Basis

The purpose of developing a theoretical basis for testing was to provide a baseline for comparison of the actual test results. This baseline can be utilized to determine whether the sensor is operating properly and also to extend the results to other scenarios. As an example of such a process, consider the Time Domain Tests.[6] One primary purpose of these tests was to determine the detection limits of the sensor for the case of no intervening walls, and walls of different makeup and thickness. Since there was no way to interface directly with the sensor, maximum detection range had to be measured by the use of standardized targets and human targets. The radar cross section (RCS) of human beings has been measured in the microwave region and has been determined to be on the order of 1 square meter (sm). Thus, spherical targets were utilized to provide a standardized RCS for the detection tests. A sphere with a radius of 11 inches has an RCS at 2 GHz (0.14 m wavelength) of 1 sm (0 dBsm). A 3 inch radius sphere at 2 GHz has an RCS of 0.0625 sm (- 12 dBsm). A 6-inch diameter precision metal sphere and an 11 inch sphere made from a rubber ball and foil were used to bracket the RCS of a person. The attenuation of the sensor signal through the wall can be determined from the equation:

$$\alpha \text{ 2-Way (dB)} = -40 \log(\text{Max Range without wall}/\text{Max Range With wall}) \quad (1)$$

The above measurements provided information on the ability of the sensor to detect moving targets with radar reflectivities approaching that of humans through walls of various types.

Probability of false alarm tests involved measuring the ability of the sensor to detect humans though a wall and to assess the false alarm rate. The sensor was located in the adjacent office next to a large room and placed facing the common wall with the large room as shown in Figure 9. An operator monitored the sensor and noted time and range

of various detections within a specific time interval. Persons entered the large room within the field of view of the radar at random intervals unseen by the sensor operator to provide for a double blind test scenario. There were some intervals when no one entered the room, and some where one or more persons entered the room. The number of data points required to provide for a statistically valid confidence interval is given by:[7]

$$N = (2Z\sigma/1-\alpha)^2 \tag{2}$$

Where: N is the number of required independent samples;

S is the standard deviation of the data;

Z is the normalized variable = 1.645 for 95% confidence level;

α is the confidence interval.

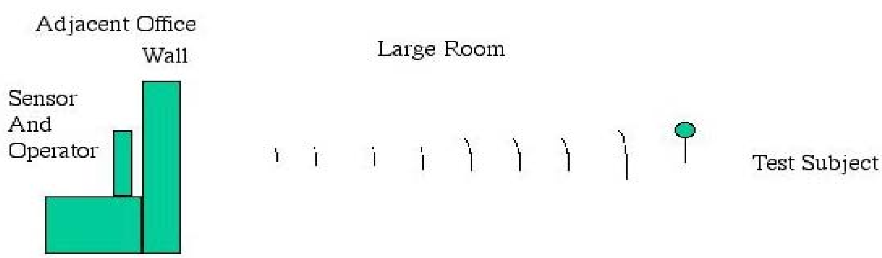

Figure 9. Scenario for Time Domain probability of detection measurements.

For a confidence interval of $\pm$ 1 at a confidence level of 95%,

$$N=[(2)(1.645)\sigma/2]^2 = 2.7\sigma^2 \tag{3}$$

As an example, if $\sigma = 10$, then N = 270 points. Since the data from the sensor is binary (1 = detection, 0 = no detection), σ can be inferred from a plot of the probability of detection versus range. The 84% point - 16% point = 2 σ assuming the median and the mean values are close (symmetrical distribution). Thus, the distance of the person entering the room from the sensor will be predetermined and measured each time.

2.2.5 Availability and Location of Sensor

The location of suitable facilities and test personnel, as well as the location of the sensors were primary determiners of the location of tests. For the case of the Trex sensor, only a short time was available for testing, and the sensor required hands-on operation by Trex Personnel. Thus, the evaluation was conducted as a demonstration at the AFRL Rome facility rather than as a full blown test. For the Time Domain sensor, the equipment was located at AFRL, Rome, and had been ruggedized for operation by persons other than the developer. Also, facilities were available in the Rome area to perform the tests. Finally, for the JAYCOR sensor, they were ruggedized and easy to ship. Since the best facilities for test and evaluation were available at RADC facilities in Atlanta, GA, the tests were performed there followed by a demonstration at the AFRL, Rome facility.[8]

2.3 Sensor Test and Evaluation

2.3.1 Trex Thermovision™ Radiometric Imager

2.3.1.1 Test Description

The Trex Enterprises sensor was demonstrated at the AFRL, Rome, NY facility in the fall of 2001. Due to the fact that the sensor was a breadboard rather than a prototype, and due to the fact that it was scheduled for other testing on a short schedule, it was decided to perform a demonstration of the sensor rather than a full blown test. A prototype sensor will be available for detailed testing eventually.

A key element in the performance of a MMW radiometer is the minimum detectable temperature difference $\Delta T_{min.}$ Measurements have determined that a ΔT_{min} of 1 to 2 K is required to reliably detect weapons under clothing for indoor conditions, and a ΔT_{min} of 5 to 10 K is required to detect weapons under clothing for outdoor conditions.[3] (The difference in sensitivity requirement for outdoors is due to the illumination of the weapon by the relatively cold sky outdoors.) Thus, measurement of ΔT_{min} was desirable, but not a possible task under the conditions of the demonstration. As an alternate procedure, the air temperature both indoors and outdoors was measured to provide an estimate of ΔT_{min}.

A type of calibration of the Trex sensor is illustrated in Figure 10 which shows a view of the Trex Enterprises MMW radiometer antenna undergoing a form of calibration in which the antenna is covered with absorber. The absorber provides a non-reflective temperature source (of known temperature) to the antenna in order to calibrate the receiver. Using this technique Trex reported a calculated value of ΔT_{min} for the sensor under test of about 5K.

The actual evaluation of the sensor's ability to detect concealed weapons was carried out by having individuals walk into the field-of-view of the system with various types of outer clothing with either weapons, innocuous items, or nothing under their clothing as shown in Figure 11 in which an individual has a Glock semiautomatic pistol hidden under a coat in his back. A typical sensor image from a demonstration of the Trex Enterprises MMW radiometer conducted at AFRL, Rome, NY, in the fall of 2001, is shown in Figure

12, which compares optical, infrared, and MMW radiometric images of the subject shown in Figure 11.

2.3.1.2 Summary of Test Results

Table 5 gives the specific parameters for the demonstration conducted with the Trex sensor. The first measurements were performed with the test subject standing outside a high bay area under a clear sky with an air temperature of 36°F. For this case the two weapons, a Glock and a revolver, were easily detectable. The equation for the apparent temperature of a metal object at 100 GHz in which both sky and ground illuminate the object is

$$T_{measured} = E\varepsilon\, T_{ground} + E(1-\varepsilon)T_{sky} + (1-\varepsilon)\,(T_{air} + T_{ground})/2^{*} \qquad (4)$$

where: E is the antenna efficiency;

ε is the emissivity of the ground;

T is the temperature as subscripted.

Figure 10. MMW radiometer lens under calibration conditions.

Figure 11. Test subject with Glock pistol in back, under coat.

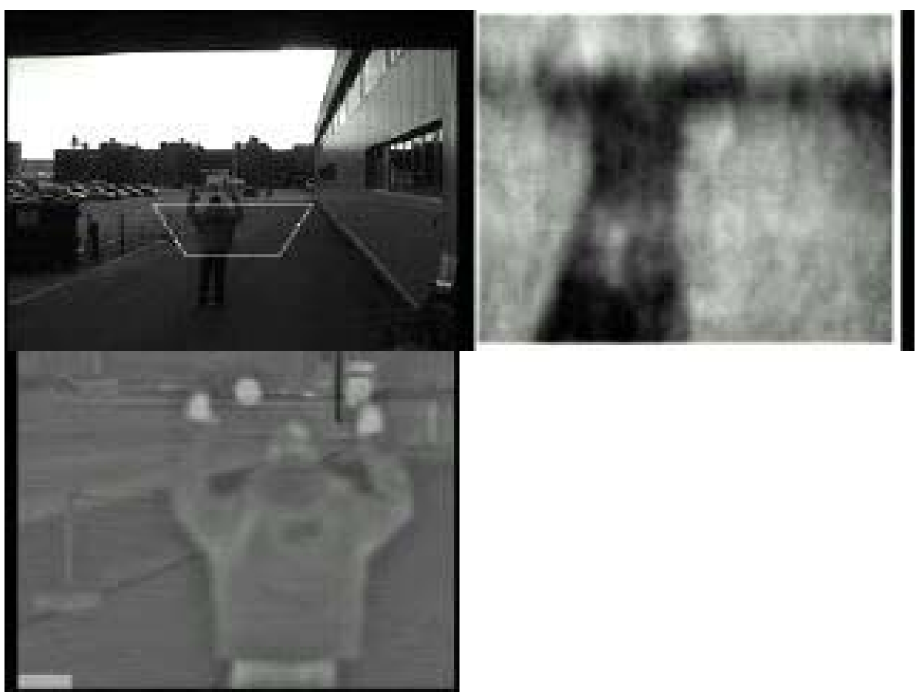

Figure 12. Imagery of test subject in Figure 5; optical (top-left), infrared (bottom-left), MMW radiometer (top-right).

TABLE 5. KEY ENVIRONMENTAL PARAMETERS FOR TREX DEMONSTRATION

Clothing	Weapon	Air Temperature	Sky Temperature	Weapon Detected?
Nylon Filled Parka	None	275.2K (36^oF)	60K*	No
Nylon Filled Parka	Glock	275.2K (36^oF)	60K*	Yes
Nylon Filled Parka	Revolver	275.2K (36^oF)	60K*	Yes
Nylon Filled Parka	None	286.3K (56^oF)	286.3K**	No
Nylon Filled Parka	Glock	286.3K (56^oF)	286.3K**	No
Nylon Filled Parka	Revolver	286.3K (56^oF)	286.3K**	No

*Estimated radiometric temperature of clear sky at 95 GHz[9]
**Indoor temperature of roof and walls.

Assuming an antenna efficiency of 50 %, an air and ground temperature of 275.2K from Table 5, a sky temperature of 60K from Table 5, and an assumed emissivity of 0.8 for the ground, the apparent temperature is calculated to be:

$$T_{measured} = (0.5)(0.8)(275.2K) + (0.5)(1-0.8)(60K) + (1-0.8)(275.2K+275.2K)/2 \quad (5)$$

$$T_{measured} = 171.12K \quad (6)$$

For the person's body which is presumably at a temperature of 98^oF (309.7K) and emissivity of 0.8, the measured apparent temperature would be:

$$T_{measured} = E\varepsilon\, T_{ground} + E(1-\varepsilon)T_{body} + (1-\varepsilon)\,(T_{air} + T_{ground})/2 \quad (7)$$

$$T_{measured} = (0.5)(0.8)(275.2K) + (0.5)(1-0.8)(309.7K) + (1-0.8)(275.2K+275.2K)/2 \quad (8)$$

$$T_{measured} = 196.09K \quad (9)$$

The temperature differential is thus 196.09K-171.12K = 24.97K. The radiometer with a ΔT_{min} of 5K can easily detect the metal objects.

However, when the subject was moved indoors to the bay so that the illuminating sky, air, and ground temperatures were 286.3K, the apparent temperature of the metal weapons became 200.4K while the apparent body temperature became 202.75 leaving a temperature contrast of only 2.35K. This small apparent temperature differential could not be detected by the sensor.

Digital movies of the Trex sensor display similar to the display shown in Figure 12 were collected for the cases of outdoors with no weapons and outdoors with two guns located in the front and in the back. These are being used presently for automated weapon detection signal processing efforts. No data were collected for the indoor measurements since the weapons were not visible on the display.

Obvious future improvements to the system need to involve better sensitivity if weapons are to be detected indoors. Also, a smaller package is highly desirable along with automated detection of weapons shapes.

2.3.2 Time Domain TWS Sensor

2.3.2.1 Test Description[10]

This section discusses the test procedures for the various tests that were performed as a part of the sensor evaluation. The tests involved determining the ability of the sensor to detect objects through walls, and the probability of detection and false alarm performance for varying environmental conditions, target persons, and range.

2.3.2.1.1 Detection Range Performance

This experiment was performed to determine key characteristics of the sensor performance including the maximum range of detection as a function of wall type or number of walls, and attenuation of each wall type. The first set of measurements was performed using a set of standard targets with a radar reflectivity as similar to that of a person as feasible. The second set of measurements was performed using real people as targets. These measurements are discussed below.

The purpose of these tests was to determine the detection limits of the sensor for the cases of no intervening walls and walls of different makeup and thickness. Since there is no way to interface directly with the sensor, maximum detection range had to be measured by observation of detections on the display standardized targets and human targets. The radar cross section (RCS) of human beings has been measured in the microwave region and has been determined to be between -10 dB relative to a square meter (dBsm) and +20 dBsm as compared to the RCS of a metal sphere[11]. A sphere has several advantages for use in measuring RCS including: the RCS has no orientation dependence, the RCS is easily calculable, and at low frequencies calibration spheres can be easily created from foil-covered rubber balls. Thus, metal spherical targets were used to provide a standardized RCS for the detection tests.

A precision 6-inch diameter sphere obtained for a previous test was used for this test as well. One problem with using a large diameter sphere with the Time Domain system is the very short range resolution of less than 1.2 inches, i.e. 0.4 nanoseconds (ns). For a sphere to provide the appropriate RCS, both the initial reflection from the front face and the creeping wave reflection must be received by the radar. The creeping wave is delayed in time, by the time required for the wave to travel around the sphere and back to the front, equal to $\pi D/c$ where c is the speed of light and D is the diameter. For the 6-

inch diameter sphere (0.152 m diameter) and the speed of light equal to 3 x 10^8 m/s, the time is 1.59 ns. In order for the reflection of a sphere to be valid for the Time Domain system, the sub-nanosecond range resolution must be averaged in range to at least 3.2 nanoseconds (0.956 m).

Another problem with using a metal sphere as an RCS target at low frequency is the potential interaction of the creeping wave with the initial reflected wave. Figure 13 shows a curve of the effect on the apparent RCS of a metal sphere when the ratio of the electrical circumference of the sphere ($\pi D/\lambda$) is between 0.1 and 10. When the electrical path length exceeds 10 the RCS is essentially independent of frequency.

From Table 3 the median frequency for the Time Domain system is 2.0 GHz and the minimum frequency is 2.0 – 1.38 GHz equals 0.62 GHz. At 0.62 GHz, λ equals 0.48 m. For a 0.152 m diameter sphere, $\pi D/\lambda$ equals approximately 1. At 2 GHz, $\pi D/\lambda = 3.2$, and at 3.38 GHz $\pi D/\lambda$ equals 5.0. From Figure 7, this puts the sphere right in the middle of the "resonance" region. Thus, it was obvious that a larger sphere was needed.

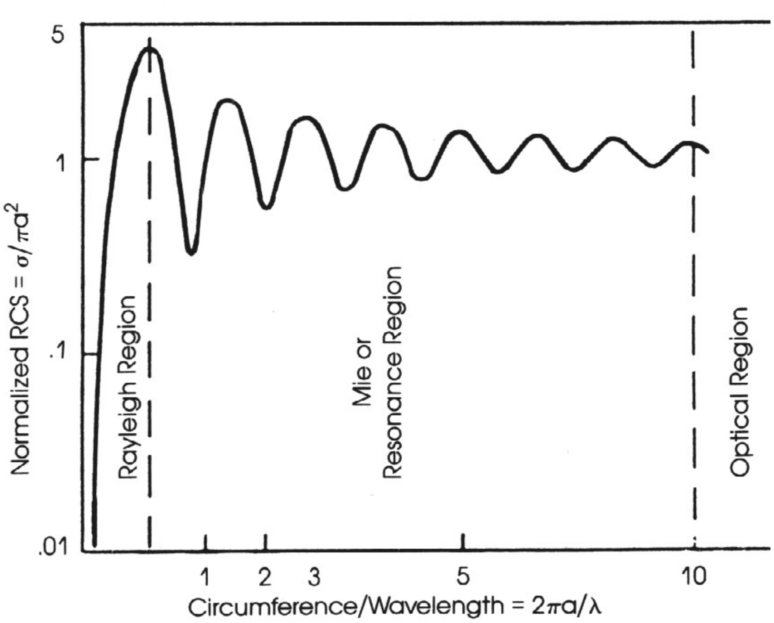

Figure 13. RCS of a sphere as a function of electrical circumference.[11]

A 12-inch diameter ball and an 18-inch diameter ball were purchased and covered with foil as shown in Figure 8. They were then suspended from the ceiling of the laboratory room via nylon net and line as shown in Figure 14. Although the foil does not appear to be optically smooth, at the shortest wavelength of the Time Domain system (8.875 cm) the "crinkles" in the foil are much smaller than 1/10 of a wavelength (0.8875 cm or 0.35-inch) so that the sphere appears electrically "smooth".

2.3.2.1.2 Estimating Attenuation

The minimum detectable range for the 12-inch sphere was measured by varying the distance from the sphere to the sensor in small increments until the sphere could not be detected. The 12-inch sphere could only be detected out to a distance of 16 feet (4.85 m). Since it was necessary to maximize the sensitivity as much as possible for the wall measurements, an 18-inch sphere shown in Figure 14 was used. The 18-inch sphere measured maximum detectable distance in the clear was found to be 28 ft. (8.48 m) which was ideal for our measurements since the maximum instrumented range for the sensor was 30 ft. 9.09 m). Next the sensor was placed with various types of walls between it and sphere as shown in Figure 11. The sphere was moved in range towards the sensor until it was detectable and the new range recorded. The attenuation of the sensor signal through the wall was determined from the equation: [12]

$$\alpha_{\text{2-Way}}\,(\text{dB}) = -40\log(\text{Max Range without wall}/\text{Max Range With wall}) \qquad (10)$$

Table 6 gives the results of the attenuation measurements. The attenuation of 1 sheet of an office partition yielded an attenuation of –0.83 dB while 2 partitions yielded –3.11 dB. The attenuation looking through 2 partitions should be roughly twice the attenuation of 1 partition in dB. Since the attenuation between the 2 partitions is significantly greater, there was either an error in estimating the maximum detection range of this sphere (not too surprising), or there was an interaction between the two partitions which caused more attenuation than expected.

Figure 14. 18-inch sphere suspended from the ceiling in the lab.

An interior Gypsum wall with 2 layers of drywall was found to have a 2-way attenuation of approximately –11 dB, a wooden hollow core door to have an attenuation of –6 dB, and an interior concrete block wall to have an attenuation of –18.5 dB. It was not possible to measure the attenuation of an exterior brick wall, since it was not possible to detect either the sphere or a person through the wall. Figure 11 shows the sensor held against the wall during the test. It was not determined whether the building has foil-backed insulation material or not. If foil was present, one would not expect to see through the foil as demonstrated in the measurement on foil in Table 6.

Figure 15 shows the 18-inch sphere suspended in the hallway at the Stiefvater Consultants facility in Griffiss Park for the interior block wall measurements. Note the doorway extending to the right. Although this doorway went into another company's office, persons inside this office were detected at distances up to 28 feet (8.48 m). Assuming that this distance was the maximum detectable range for a person the RCS of a person can be estimated from:

$$\sigma_{person} = \sigma_{sphere} + 40 \log(R_{max\ (person)}/R_{max\ (sphere)}) \tag{11}$$

$$\sigma_{person} = -1.8 \text{ dBsm} + 40 \log(8.48/2.878) \tag{12}$$

$$\sigma_{person} = +16.97 \text{ dBsm} \tag{13}$$

This value falls within the reported values of the RCS of a person (-10 to +20 dBsm) although it is near the high end of the range.

2.3.2.1.3 Probability of Detection/False Alarm Rate Tests

These tests involved measuring the ability of the sensor to detect humans though a wall and to assess probability of detection and probability of false alarm. The probability of detection is defined as the total number of sensor indicated target detections divided by the total number of real targets present within the field-of-view of the sensor during the test period. The false alarm rate is defined as the total number of sensor indicated detections when no target was present divided by the total elapsed data collection time in hours.

TABLE 6. SUMMARY OF ATTENUATION PERFORMANCE TESTS

Target	Calculated RCS (dBsm)	Intervening Medium	Detection Range (m)	2-Way Loss Relative to Free Space (dB)
6-inch Sphere	-11.3	None	4.85	0
12-inch Sphere	-5.3	None	6.67	0
18-inch Sphere	-1.8	None	8.36	0
18-inch Sphere	-1.8	Modular Partition	7.97	-0.83
18-inch Sphere	-1.8	2 Modular Partitions	6.99	-3.11
18-inch Sphere	-1.8	Interior Gypsum Drywall	4.39	-11.19
18-inch Sphere	-1.8	Hollow Core Wooden Door	5.79	-6.38
18-inch Sphere	-1.8	Interior Concrete Block Wall	2.878	-18.52
18-inch Sphere	-1.8	Exterior Brick Wall	0*	∞*
18-inch Sphere	-1.8	Thin Metal Foil	0*	∞*
Man	16.97***	Interior Concrete Block Wall	8.48	-18.52**

*Could not detect sphere.
** Assumed to be the same as previous measurement.
***Inferred from previous measurements

Figure 15. 18-inch sphere suspended in hallway at Stiefvater Consultants facility for interior concrete wall measurements.

It was desired to have a test bed, in which the sensor could be placed next to a wall that looked down a hallway corridor so that range dependence of detection could be evaluated. Unfortunately, it was not possible to find a suitable test area with the 3 buildings to which there was access. Thus, the sensor was located in adjacent rooms next to hallway corridors so that people targets were passing tangentially to the sensor rather than radially as shown in Figure 16. In order to preserve the "double blind" aspect of the test, the sensor operator was not able to see or hear people walking down the hall on the other side of the wall. He noted the time and range of various detections within a specific test time interval. The test monitor was positioned on the other side of the wall, and he noted the time and number of persons walking by the corridor during the test interval. If a long period occurred without any "targets of opportunity" passing by, he would walk down the hall at random times so as to be a target.

2.3.2.1.3.1 Drywall Detection Tests

The detection of targets through interior drywall tests were conducted in an AFRL building located at 32 Brooks Road, Rome, NY. The sensor was located on a table inside a laboratory room facing a dry wall which separates the laboratory from a hallway. Figure 17 shows the sensor in place next to the interior drywall, and Figure 18 shows the edge of the drywall viewed from the doorway. It is possible that the wall was composed

of 2 sheets of 5/8-inch dry wall with metal studs. It was not determined whether the wall contained any insulation or not. Obviously, no metal sheathing was contained in the wall since the sensor was able to penetrate the wall.

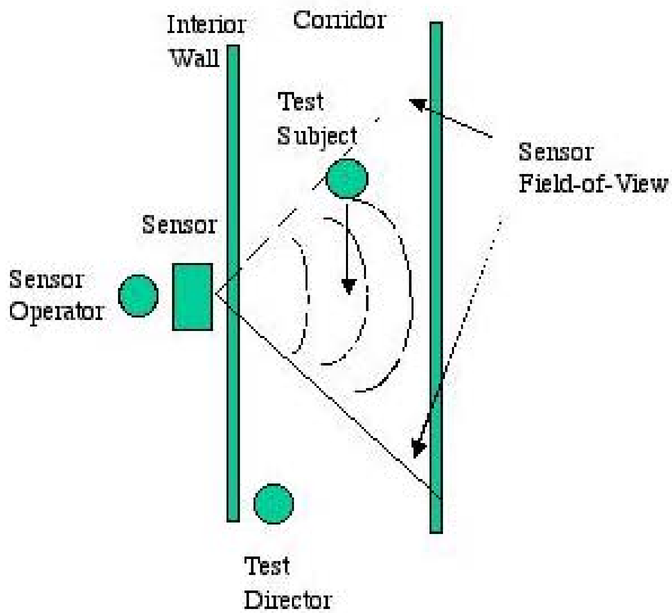

Figure 16. Representation of "birds eye view" of test scenario for probability of detection and probability of false alarm tests.

The test monitor was located in the hallway far enough away from the laboratory so as to be out of the sensor field-of-view yet able to see when people passed within the sensor field-of-view. The doorway was kept closed during the tests. Tests were run on 5-minute intervals so as to allow the operator to take a break between runs. (A major problem with any manually operated sensor is the fatigue experienced by an operator after a few minutes of continuous operation.)

The number of data points obtained during the test was limited by the test time available, and the number of targets of opportunity plus simulated events by the test monitor. Table 7 summarizes the results from the first test with the dry wall. During an approximately 8 hour test period, a total of 38 minutes of testing time was conducted, 60 real targets (persons) were encountered, and 55 of these were detected by the sensor. A total of 12 false alarms were detected which leads to a false alarm rate of 24 per hour. The causes of the false alarms were not determined: they could be noise induced, they could be due to persons in the laboratory room behind the sensor which were detected because of reflections off of the dry wall, or they could be real targets that were detected outside the expected sensor field-of-view (such as through a sidelobe). The average detection range

was 3.85 m. The distribution of detection ranges was bimodal with the most likely detection range occurring at either 3.03 m or 4.55 m. This was likely due to the fact that these were the typical ranges to someone walking on either the left or right side of the hall way as they passed into the sensor antenna field-of-view.

Figure 17. Sensor position next to drywall for first test.

Figure 18. Edge of interior drywall viewed from doorway.

TABLE 7. SUMMARY OF DRYWALL DETECTION EXPERIMENT

Parameter	Value
Total Number of Real Targets Encountered	83
Total Detections	77
Total Misses	5
Total False Detections	13
Probability of Detection	0.928
Probability of Miss	0.072
False Alarm Rate*	15.9 per Hour
Average Detection Range	3.85 m
Bi-Modal Detection Ranges	3.03 m, 4.55 m
Per Cent of Time Correct Target Travel Direction Was Determined	51.1%

*Total elapsed data collection time was 49 minutes over 8 hours total test time.

Some of the time, it was possible to determine the direction of travel of the targets. As shown in Table 7 the correct direction of travel (left-to-right or right-to-left) was determined about half the time which may mean that the direction was a random guess.

2.3.2.1.3.2 Interior Concrete Wall Detection Tests

The interior concrete wall tests were performed at the Stiefvater Consultants office in the Griffiss Office Park. The sensor was located on a table within an office as shown in Figure 19 and aimed through an interior concrete wall at a hallway. The composition of the wall was determined by removing a suspended ceiling tile near the wall and describing the wall from the top. Figure 20 shows a cross-section of the 16“wall, giving an estimate of the materials present. The sensor was located on the Gypsum board side of the wall, and the hallway wall contained the “smooth coat” and wallpaper.

After the attenuation tests were conducted, a test monitor was located in the hallway to monitor persons passing the sensor site, sensor operator noted detections on a 5-minute at a time basis similar to the drywall detection tests. Table 8 summarizes the results from the interior concrete block wall test.

Figure 19. View of Time Domain Sensor location for tests.

The total number of target encountered is similar to the wall board tests, but the probability of detection is slightly lower. Since the measured attenuation from Table 6 through the concrete wall is 8 dB higher than the wall board wall, this is not unexpected. Interestingly, the false alarm rate is similar for both experiments, which tends to indicate that the false alarms are noise generated since they seem to be independent of the environment. The average detection range was slightly higher for the concrete block wall than the wall board wall. Again, this is logical due to the higher attenuation of the concrete block wall. In summary, the detection performance was quite good for the interior block wall although it was lower than the performance for the wall board wall.

The ability to determine the target crossing direction was greatly reduced to a little over 10%. This was mainly due to only getting one or two “hits” on the target as it passed by due to the larger wall attenuation.

2.3.2.2 Summary of Test Results[10]

This section summarizes our overall impressions of the operation of the Time Domain sensor during the 4-day test period. Specific comments are listed below:

- The sensor operated reliably during the test period. There was no “down time” due to sensor failures. The packaging and case appears to be reasonably rugged, and withstood our “man-handling” with no problems. However, the sensor was not operated in adverse weather conditions such as rain, etc.
- There were some problems with charging the batteries. In particular, it was sometimes difficult to tell if a battery was actually charging, or whether it was fully charged. As a result, some test time was lost due to uncharged batteries.

- The display was relatively easy to interpret, and after some familiarization, the sensor operator was able to tell the direction of travel of a target, and occasionally whether there was more than 1 target present.
- The automatic threshold detection mode did not function correctly. When operating in the automatic mode, the display would periodically “bloom” with numerous detections, although no target was present as shown in Figure 21. Fortunately, it was determined that the operation was reliable in the manual threshold mode. For set up, the manual threshold was lowered until the display “bloomed” with noise, and then raised the threshold until the noise-generated targets disappeared. This was the procedure followed during the detection tests.
- The sensor transmitter was triggered by depressing and holding a trigger inside the sensor handle. After 30 seconds or so, holding the trigger became tiring. The solution was to use an adjustable bar clamp to hold the trigger in a depressed state during testing.

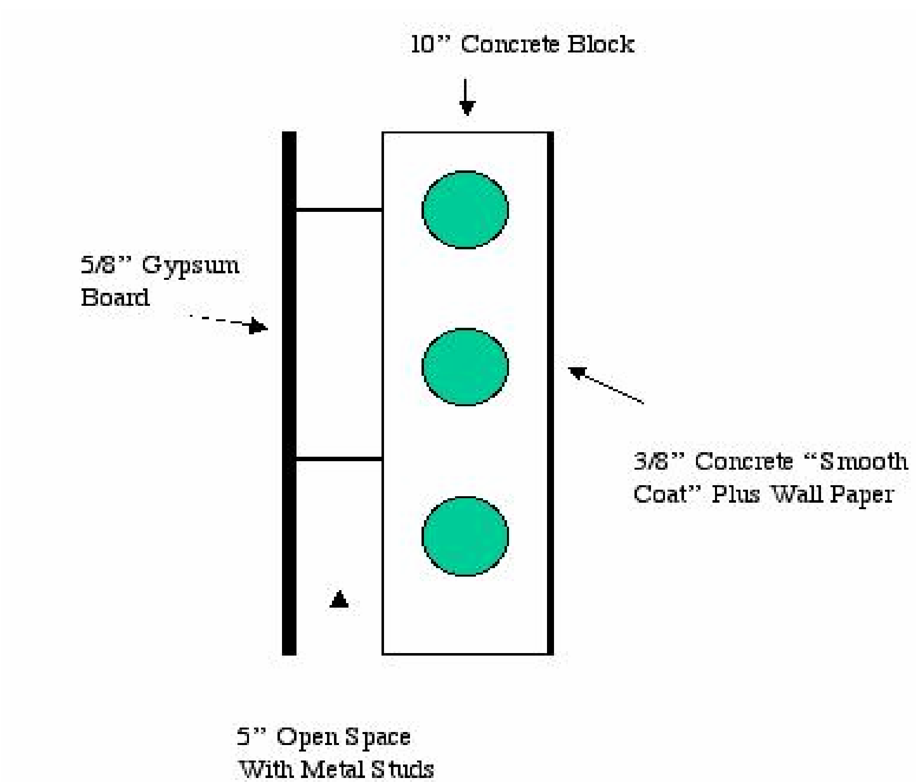

Figure 20. Top view of cross-section of the interior of the wall.

TABLE 8. SUMMARY OF CONCRETE WALL DETECTION EXPERIMENT

Parameter	Value
Total Number of Real Targets Encountered	69
Total Detections	57
Total Misses	5
Total False Detections	7
Probability of Detection	0.826
Probability of Miss	0.174
False Alarm Rate*	19.1 per Hour
Average Detection Range	4.33 m
Modal Detection Range	3.94 m
Per Cent of Time Correct Target Travel Direction Was Determined	11.5%

*Total elapsed data collection time was 22 minutes over 4 hours total test time.

- The operating information sent with the sensor did not give the weight, but it was too heavy for a single person to operate unless the sensor was resting on a table. The sensor was used for mobile operations with one person holding the unit against a wall while a second person monitored the display.
- It was noted that the sensor seemed to be more sensitive at detecting targets through a wall when it was located 1 or 2 feet from the wall as opposed to being against the wall. A calibrated test of this phenomenon was not performed so this result is presented only as an unverified comment.
- It was not possible to detect any targets through 2 types of exterior walls: a brick wall and a 24-inch thick block wall. It was not determined whether the walls contained a metallic vapor barrier or not. Thus, it is not known whether this inability to detect targets through these walls was due to a metallic sheath or due to excessive attenuation of the thicker exterior wall materials.

2.3.3 JAYCOR CWD-2002™ Acoustic Concealed Weapon Detector

2.3.3.1 Test Description[13]

Tests were conducted on a manufactured ultrasonic radar test range using calibration reflectors that were constructed for the purpose of the tests. These items are described below.

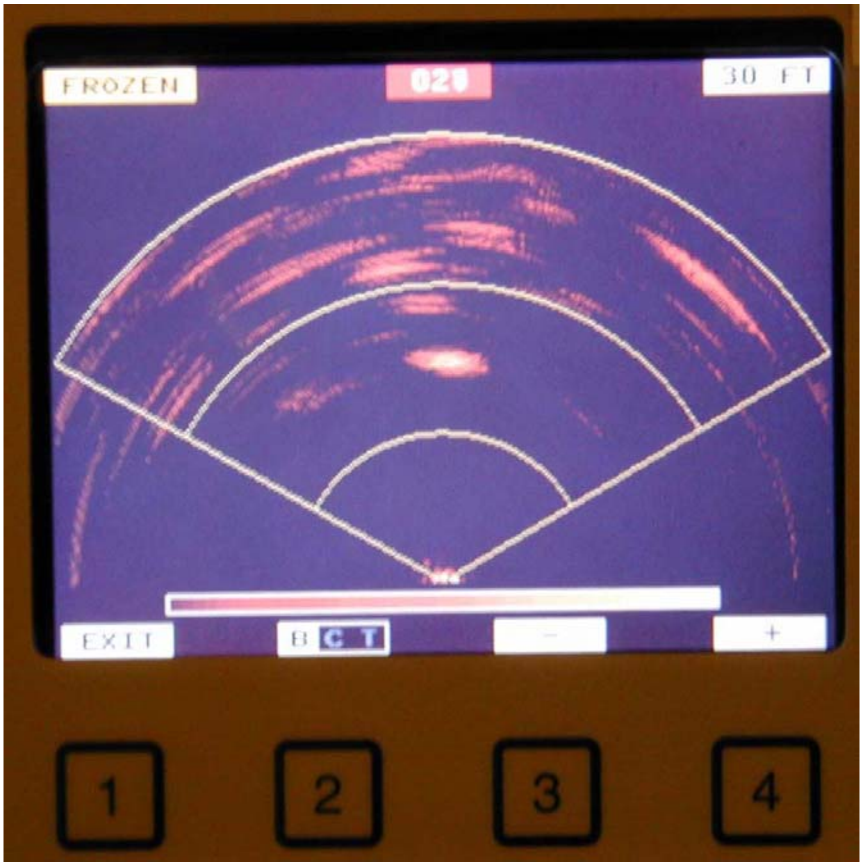

Figure 21. Display set up mode showing display "bloomed" with noise in Automatic Detection Mode.

2.3.3.1.1 The Measurement Range

The ultrasonic measurement range consisted of a mount for the concealed weapon detector under test, a target stand to hold different objects for measurement, a set of calibrated reflectors having different values of reflectance, and a measurement scale to determine the sensor-to-target distance. Figure 22 shows the basic elements used in this simple test range. The background trees are well beyond the instrumented range of the sensor. Measurements of targets placed on the target stand were made with human operators out of the field of view.

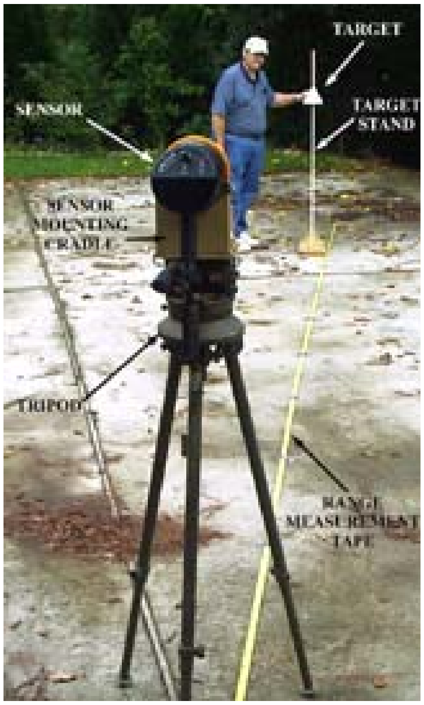

Figure 22. Down-range view of the acoustic measurement range.

2.3.3.1.2 Calibrated Trihedral Corner Reflectors

The primary calibration target constructed for this test program was the trihedral corner reflector. Corner reflectors for optics can be constructed from mirrors. Radar reflectors are generally made from metal plates that are good electrical conductors. Acoustic reflectors are constructed with a material having a relatively hard non-porous surface. The material used in constructing the ultrasonic corner reflectors for these test compared reasonably well with a metallic radar trihedral reflector of equal physical size (See Figure 23).

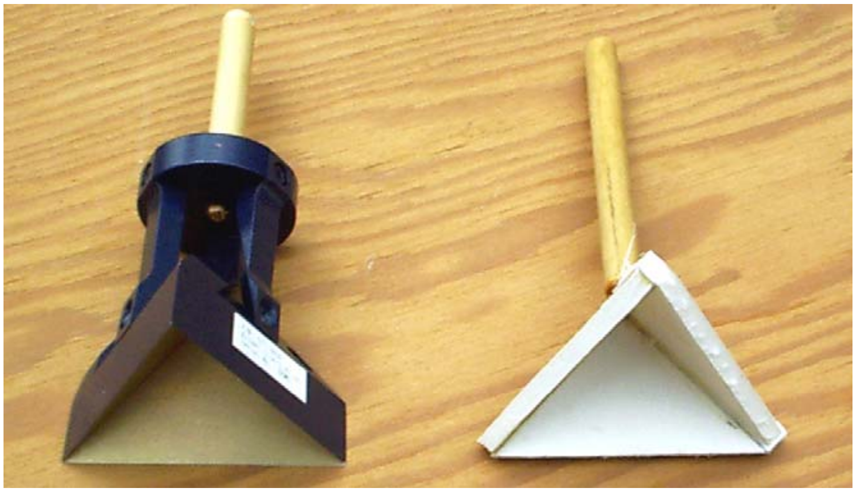

Figure 23. Corner reflectors used to compare precision metal radar reflector with ultrasonic reflector material used in these tests.

The reflectance of a single reflector is determined by the physical size of the reflector and the wavelength of the incidence wave. The reflectance for a trihedral composed of triangular sides is calculated from the formula:[14]

$$\text{ACS (dBsm)} = \frac{4\pi\, a^4}{3\lambda^2} \tag{14}$$

Where ACS is the Acoustical Cross Section of the reflector;
a is the length along the adjoining sides of the corner; and
λ is the wavelength of the incidence wave.

The physical size of each corner reflector was used to establish its calibrated reflection value. The conventional units of ACS reflectance are square meters. In this report, the theoretical values of reflectance for each reflector are given in dBsm (dB relative to a reflectance of one square meter).

A total of 25 corner reflectors were constructed for use in these measurements (see Figure 24). Each reflector was mounted on a wooden dowel to permit easy attachment in front of the reflector stand.

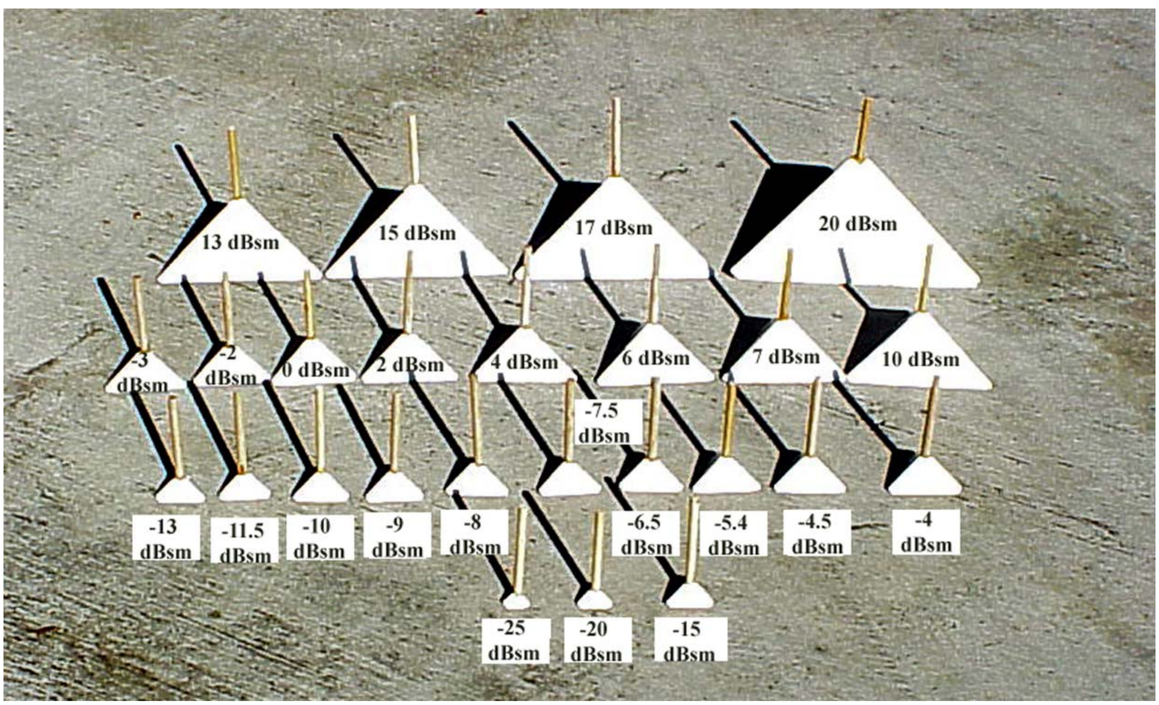

Figure 24. Trihedral corner reflector set used in the ultrasonic measurements.

2.3.3.1.3 Reflector Stand

The reflector stand (Figure 25) was made of a light-weight wood using a design that would give a minimum reflectance in the direction of the illuminating source (i.e.; in the direction of the concealed weapon detector unit). Low backscatter from the stand was accomplished by (1) sloping the vertical support member away from the source and by (2) making the side facing the detector to be similar to a knife. Several holes were drilled in the stand to accept the corner reflectors and other mounting attachments necessary to support targets and clothing articles.

One mounting attachment was designed to hold a pistol with the barrel in a downward position similar to what might be expected when carried in a holster. This attachment supported the gun on a wooden dowel that went into the barrel of the weapon (see Figure 26). The weapon could be rotated to any azimuth positions relative the sensor to determine reflectivity changes at different azimuth directions. This attachment was also adapted to support other target items such as knives, calculators, beepers, cell phones, etc.

An additional mount was made to position clothing articles in front of the corner reflector and the illuminating source as shown in Figure 27. When weapons were mounted on the test stand, a shirt or coat could be placed in front of the target to provide a controlled measurement platform that did not change when comparing the performance of different sensor units against a "concealed weapon" target. If a corner reflector having a reflectance value equal to the minimum detectable signal was used as the target, then the increase in reflectance needed to reach the same signal level at the sensor for a target covered by a garment represents the two-way losses caused by the garment.

Figure 25. Reflector/Target test stand.

Figure 26. Pistol mounted on test stand fixture.

Figure 27. Target on test stand with shirt between sensor and target.

2.3.3.1.4 Sensor Test Stand

A simple wooden sensor cradle was constructed that could be mounted on a camera tripod to provide a fixed location and fixed illumination angle for the sensor unit (See Figure 28). This mount allowed easy interchangeability when comparing the performance of several sensor units while maintaining their positions and pointing angles constant. The handle and controls of the sensor remained available to the operator.

This sensor cradle was also adopted for use on a surplus military tripod that had angle scales in both azimuth and elevation. This combination allowed any errors in the co-bore sighting of the laser pointer and the ultrasonic beam of the sensor to be measured. The center of the ultrasonic beam was determined by sweeping the beam across a corner reflector on the test stand and noting the peak position (in both azimuth and elevation) as indicated by the readout lights on the sensor unit. Pointing errors between the laser pointer and the position of peak response of the detector were recorded. The angle readout scales on this tripod are visible in Figure 29.

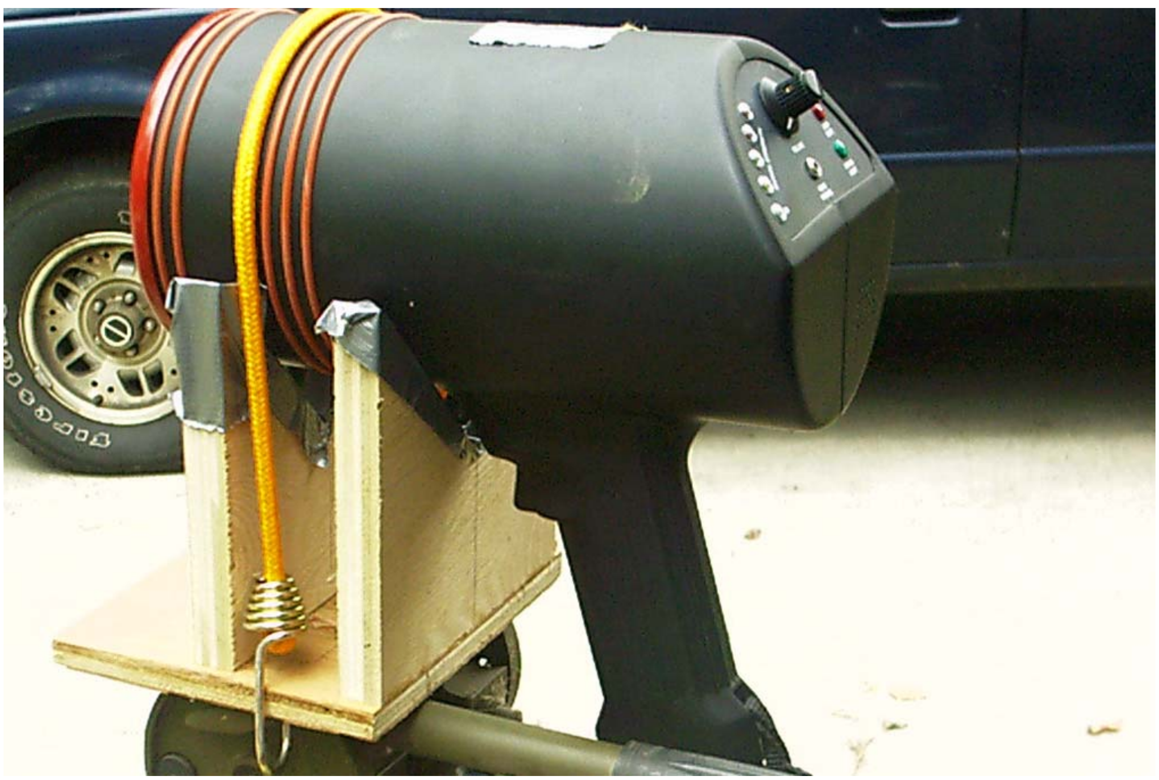

Figure 28. Sensor cradle on tripod.

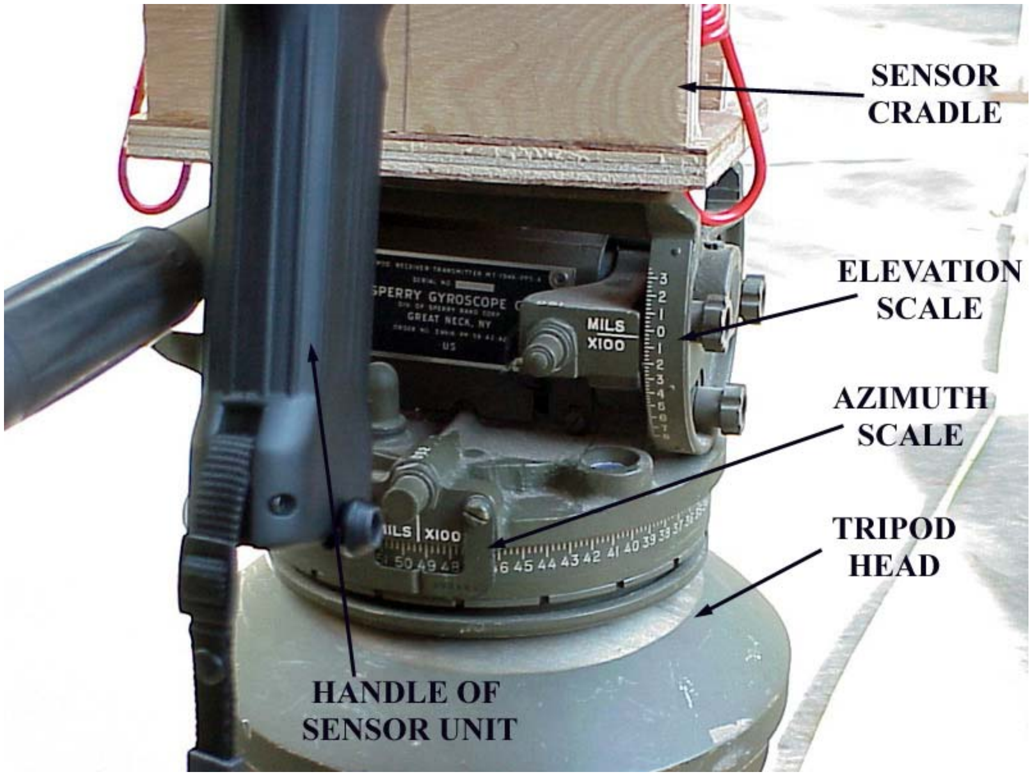

Figure 29. Azimuth and Elevation Scales on tripod head.

2.3.3.2 Summary of Test Results

2.3.3.2.1 Measurement of the Acoustic Attenuation Through Clothing

Acoustic attenuation measurements through clothing were performed on September 23, 2002. The technique used involved determining the maximum range at which a small trihedral (-5.4 dBsm) corner reflector could be detected by JAYCOR sensor number 5 (one of the most sensitive sensors received), followed by suspending various types of clothing between the sensor and the reflector.

The maximum range that our smallest reflector could be detected was established. A 30-foot metal tape was laid on the ground in order to measure the exact range between the sensor and the reflector. The maximum detectable range was established as the range upon which 1 yellow light (out of 4) was steadily lit when the sensor laser sight was bore-sighted on the trihedral. Next, an article of clothing was draped over the top of the stand as shown in Figure 30. The article of clothing was then draped over the front of the reflector as shown in Figure 31, and increasingly larger reflectors were placed behind the clothing until the (1 light) minimum detection was achieved. The difference in reflectivity between the minimum detectable cross section with and without the article of clothing placed over the reflectors represents an estimate of the 2-way attenuation due to the presence of the clothing in the path between the sensor and the reflector. Figure 32

shows a nylon jacket draped over a trihedral. For some tests the shirts were doubled in front of the reflectors to provide two layers.

Figure 30. Tee-shirt draped over top of stand behind the trihedral reflector.

Figure 31. Tee-shirt draped over the front of the trihedral reflector.

Figure 32. Nylon jacket draped over trihedral reflector.

Table 9 summarizes the results of the attenuation tests. The range used was 23 feet which was the range for minimum detectable signal on the -5.4 dBsm reflector. All measurements were conducted at this range. Using the -5.4 dBsm reflector as the starting point, larger reflectors were substituted behind the articles of clothing until a 1 light detection was achieved. The difference in the reflector cross section values is an estimate of the 2-way attenuation through the article of clothing.

Keeping in mind that Table 9 represents only an estimate of attenuation, since there are many potential error sources that cannot be accounted for by the use of this measurement method, the single layer of the shirts provides about 5 dB of 2-way attenuation while the nylon jacket provides for more than 20 dB of 2-way attenuation. Adding a second layer of the two shirts seems to more than double the attenuation. This larger attenuation cannot be accounted for unless it is some sort of interference cancellation effect.

In summary, the attenuation measurements imply that it may be possible to detect a weapon of suitably large acoustic cross section through one or two layers of a cotton shirt, it is unlikely that a weapon can be detected under a nylon jacket.

2.3.3.2.2 Measurement of the Acoustic Cross Section of Weapon and Innocuous Objects

On October 2, 2002 and November 15, 2002, acoustic reflectivity measurement was performed of the target set that was selected for the JAYCOR sensor evaluation. The target set includes the following:

- Model 19 Glock semi-automatic 9-mm pistol;
- Smith & Wesson 5 shot 38 cal. revolver;
- USMC Bayonet with 6-inch blade;
- Swing-blade knife with 4-inch blade;
- 2-shot 38 cal. Derringer;
- Cingular™ cell phone;
- 3"X6" Casio calculator with plastic cover.

TABLE 9. ACOUSTIC ATTENUATION MEASUREMENTS

Clothing Type	Range (ft.)	MDC *(Bare Reflector dBsm)	MDC* (Behind Clothing dBsm)	2-Way Attenuation (dB)
Cotton Shirt (Single Layer)	23	-5.4	0	5.4 dB
Cotton Shirt (Two Layers)	23	-5.4	10	15.4
Flannel Shirt (Single Layer)	23	-5.4	0	5.4
Flannel Shirt (Two Layers)	23	-5.4	7	12.4
Fleece-Lined Sweat Shirt (Single Layer)	23	-5.4	7	12.4
Fleece-Lined Sweat Shirt (Two Layers)	23	-5.4	20	25.4
Nylon Jacket	23	-5.4	20	25.4

*MDC - Minimum detectable acoustic cross section

The methodology consists of determining the maximum range that would achieve a steady 1-light detection for each object. For these measurements, Units 5 and 7 were used, two of the most sensitive sensor units. The objects were moved in both the horizontal and vertical planes to achieve the peak detection range.

Table 10 summarizes the results obtained from the reflectivity tests. It was determined that all of the test objects were very specular in nature. That is, they only exhibited a strong enough return to be detectable at any range by the sensor when they were oriented such that they were perpendicular to the line-of-sight from the sensor to the object. Thus, they provided a "mirror-like" reflection characteristic as shown in Figure 32. The only exception was the revolver which (due to its cylindrical barrel) was insensitive to orientation along the axis perpendicular to the cylinder longitudinal axis. However, it was still very sensitive to orientation along the longitudinal axis, providing a return only when this axis was perpendicular to the line-of-sight to the sensor.

The innocuous objects generally could be detected at shorter ranges than the weapons leading to the supposition that innocuous objects are more likely to be detected than weapons. At the end of the reflectivity measurements, several tests with Glock under a T-shirt and under a nylon jacket were tried. There were no detections for the Glock under the T-shirt but there were detections on the nylon jacket whether the Glock was present or not. This leads to the conclusion that the nylon jacket is very reflective, since the Glock was not actually detected under the jacket.

TABLE 10. SUMMARY OF REFLECTIVITY MEASUREMENTS

Sensor Unit No.	Object	Orientation	Detection Range (ft.)	Comments
5	-5.7 dBsm Trihedral	Face Perpendicular to Sensor	23	
5	Glock	Broadside	26.5*	Very Specular
5		Barrel-On	No Detection @ 4 ft.	
5		Butt-On	5	Very Specular
5	Revolver	Broadside	25	Very Specular
5		Barrel-On	No Detection @ 4 ft.	
5		Butt-On	No Detection @ 4 ft.	
5	Bayonet	Broadside	15	Very Specular
5		Edge-On	No Detection @ 4 ft.	
5	Derringer	Broadside	11.5	Very Specular
5		Butt-On	No Detection @ 4 ft.	
5	Cell Phone	Front	8	Very Specular
5		Back	22	Very Specular
5		Side	22	Very Specular
5	Calculator	Front	26.5*	Very Specular
5		Side	26	Very Specular
5	Nylon Coat	Front	23	No Object Present Under Coat
7	-5.7 dBsm Trihedral	Face Perpendicular to Sensor	25.25 ft.	
7	Glock	Broadside	25.25 ft.	Very Specular

* Note: 26.5 ft. is the maximum range at which the JAYCOR sensor operates. Thus, the actual detection range may be further than indicated.

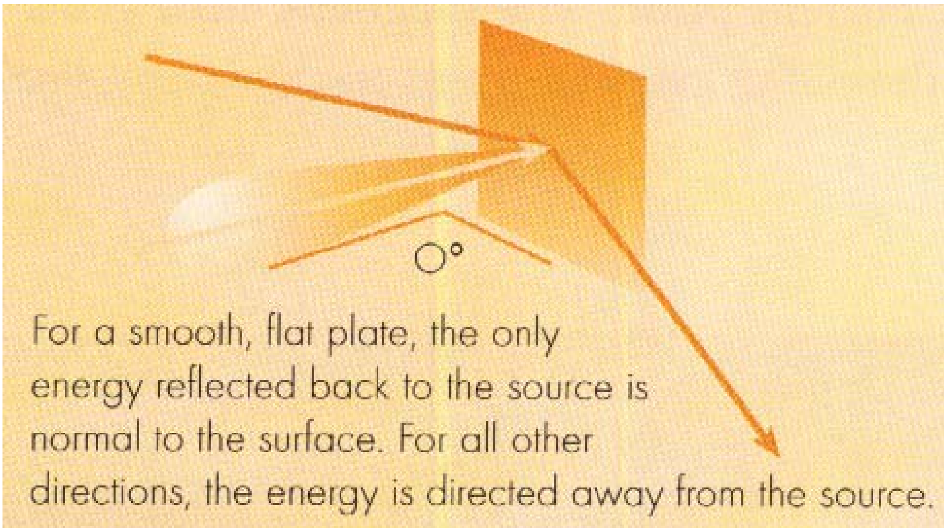

Figure 33. Illustration of specular reflection of a transmitted wave from a flat plate.[15]

2.3.3.2.3 Detection Sensitivity Measurements

The final test involved measuring the minimum detectable acoustic cross section for each of the sensors at a fixed range. Twenty-five (25) feet was chosen as the range for comparison since that is the maximum advertised range for the sensors. As in the past the steady illumination of 1 light was selected as the indication of minimum detectable signal for each sensor. Each sensor was boresighted on a large cross section trihedral reflector so that the beam center (as opposed to the laser spot) was aligned with the reflector. Smaller reflectors were then substituted until 1-light detection was achieved.

Table 11 gives the results for the sensitivity measurements. Note that for units 001 and 003 there was an indication of 1 steady light plus 1 other light that was intermittent. The next smaller trihedral was 0 dBsm, and no lights were detected for that reflector. Thus, the sensitivity was probably slightly less than the +7 dBsm shown.

TABLE 11. JAYCOR SENSOR SENSITIVITY MEASUREMENTS

Sensor Number	Minimum Detectable Cross Section (dBsm)
001	+7
002	0
003	+7
004	-6.5
005	-10
006	-13.5
007	-10
008	-7.5
009	-6.5
010	-6.5

However, it can be seen that there is a total of more than 20 dB difference between the best and worst of the 10 sensors. When you factor in the antenna misalignment problems the difference is even worse.

2.3.3.2.4 Probability of Detection/False Alarm Rate Tests

Detectability tests were conducted by placing an object on a test subject and having him slowly rotate his body while the sensor scanned his body in a cross pattern as recommended by the JAYCOR instruction manual.[16] Any detections of the object were noted as well as any false detections. When an apparent detection occurred for an object, the object was removed and the scan procedure was repeated to confirm that the detection was due to the object and not something else. Figures 34 through 40 show the seven test objects and their placement on the body. In each case the object was placed in a realistic location on the body.

Table 12 summarizes the data from the tests. For each object the sensor was scanned in an up/down, left/right pattern while the subject slowly rotated. The maximum number of lights that were lit during the test run is indicated.   One light is a minimum detection and 4 lights is a maximum detection. Some detections from the clothing were also noted. The table shows that the two pistols were very hard to detect while the bayonet and the innocuous items were much easier to detect.

Figure 34. Glock pistol in belt.

Figure 35. Revolver in belt.

Figure 36. Bayonet on side.

Figure 37. Folding knife in side pocket.

Figure 38. Pager on side.

Figure 39. Cell phone in side pocket.

Figure 40. Calculator in breast pocket.

Returns from both a denim jacket (Figure 41) and a leather belt were noted. The denim jacket registered returns from the brass buttons on the front and a much larger return from the 2 seams in the rear when they were perpendicular to the line-of-sight to the sensor.

Figure 41. Denim jacket seam with large acoustic return.

Tests were also performed in order to discern the effect of placing the objects under clothing. The results are summarized in Table 13. As can be seen, the thin cotton shirt cover greatly reduced the ability to see the objects, and none could be seen through the denim jacket although false alarms were generated by the jacket buttons and seams as indicated previously. It is significant to note that none of the objects provided a 4-light alarm when covered by clothing.

TABLE 12. SUMMARY OF TESTS FOR DETECTABILITY
OF UNCOVERED OBJECTS

Object	Placement	No. of Lights Lit	Comments
Glock	Front	0	Weapon orientation not perpendicular to line-of-sight
	Side	0	Weapon orientation not perpendicular to line-of-sight
	Back	4	Weapon orientation perpendicular to line-of-sight
Revolver	Front	0	Weapon orientation not perpendicular to line-of-sight
	Side	2	Weapon orientation perpendicular to line-of-sight
Bayonet	Side	4	Cylindrical shape reduced orientation requirement
Folding Knife	Side	2	Cavity in side reduced orientation requirement
Pager	Side	2	Object orientation perpendicular to line-of-sight
Cell Phone	Side	1	Object orientation perpendicular to line-of-sight
Calculator	Front	4	Object orientation perpendicular to line-of-sight
Denim Jacket	Back Seam	4	Object orientation perpendicular to line-of-sight
	Front Buttons	2	Object orientation perpendicular to line-of-sight
Leather Belt	Side	1	Object orientation perpendicular to line-of-sight
	Back	1	Object orientation perpendicular to line-of-sight

TABLE 13. EFFECTS OF COVERING TEST OBJECTS

Object	Cover	No. of Lights Uncovered	No. of Lights Covered
Glock	Cotton Shirt	4	2
	Denim Jacket	4	0
Revolver	Cotton Shirt	2	1
Pager	Cotton Shirt	2	0
Cell Phone	Blue Jean Pocket	1	1
Calculator	Denim Jacket	4	1
Bayonet	Denim Jacket	4	0
Folding Knife	Cotton Shirt	2	1

2.3.3.2.5 Summary

Ten JAYCOR CWD-2002 acoustic concealed weapon detection sensors were evaluated. The evaluations included: physical condition of the units, relative sensitivity, antenna alignment with the laser pointer, and the ability to detect weapons and innocuous items on a human body with and without concealing clothing. Additional tests were performed to estimate the acoustic cross section of weapons and innocuous objects, the attenuation of objects due covering clothing, and the attenuation of the intervening air.

Since there was a requirement to perform noninvasive testing of the JAYCOR units, the measurements were referenced to acoustic trihedral corner reflectors, relying on the close correspondence of acoustic scattering effects to RF scattering properties. The findings are summarized below.

2.3.3.2.5.1 JAYCOR System Advantages

The JAYCOR sensors exhibited a number of positive aspects during the testing. These include:

- The packaging was compact, lightweight, and the controls were easy to operate.
- The batteries were easy to change, and seemed to charge rapidly.
- The best of the units were very sensitive, being able to detect a -5.4 dBsm target or smaller at 25 feet.
- Sensor sensitivity stability from day-to-day appeared to be good.

2.3.3.2.5.2 JAYCOR System Disadvantages

The JAYCOR sensors also exhibited a number of negative aspects (or deficiencies) during the testing. These include:

- The units did not travel well. Several were damaged upon receipt.
- The laser pointer was difficult to see in bright sun light. It was reasonably visible on cloudy days.
- There was a significant variability among the 10 unit evaluated both in antenna beam - laser pointer alignment errors and sensitivity.
- Due to the specular nature of the reflections from weapons, they were only visible to the sensor when the geometry was such that the weapon surface was perpendicular to the sensor-weapon line-of-sight. (This tended to occur only when the weapon was located on a person's back, which is more vertical than the sides or front.)
- The reflections from innocuous objects and certain types of clothing such as belts and a denim jacket were larger than those of most weapons.
- No detection of weapons under clothing was observed to occur except for the case of a very thin cotton shirt which was in physical contact with the weapon.

2.3.4 Georgia Tech Research Institute (GTRI) Radar Flashlight™

2.3.4.1 Sensor Modifications

Under the contract modification GTRI was to modify the Radar Flashlight™ for remote operation and to provide the modified unit to AFRL and the NIJ for evaluation. GTRI modified the unit to operate on a tripod with a remote Palm Pilot™ display as shown in Figure 42. The signal processing of the Radar Flashlight™ was also improved to reduce the effects of motion of the sensor on the performance.

The final system consists of 4 major hardware components:

1) The Radar Flashlight with mounting bracket,
2) The tripod assembly with pan/tilt unit,
3) The Pan/Tilt unit with controller and power supply,
4) The Compaq iPAQ PocketPC™ unit with expansion pack and serial card.

The Pan/Tilt unit mounts to the top of the tripod. The Radar Flashlight clamps into the mounting bracket and then, after power-up of the Pan/Tilt system (per startup instructions provided later), to the mounting hole in the top of the Pan/Tilt unit. The PocketPC™ is meant to be hand-held, and is used remotely. More detail on all hardware systems is provided in the Design Document and individual hardware component manuals.

In addition these components, there are 4 cable sets required for operation:

1) A Communications cable set (one optional) for the PocketPC™-to-Flashlight link,
2) A Communications cable pair for the Flashlight-to-Pan/Tilt controller link,
3) A power cable for the Pan/Tilt controller,
4) A control/drive cable to connect the Pan/Tilt controller to the Pan/Tilt unit itself.

The PocketPC™-Radar Flashlight™ cable is used in either 2 or 3 sections as described below:

1) A short interface cable to the iPAQ™ itself (required). This cable or "dongle" comes with the serial interface PCMCIA card;
2) A longer standard serial cable (optional-up to 50 feet) to extend the system in the field;
3) A short special-purpose cable (required) to convert between the standard 9 pin serial cable and the Radar Flashlight mini-jack (a standard stereo connector, such as those used in headphones).

This version of the Radar Flashlight™ supports both the standard method of use (stand-alone, hand operation) and remote operation via the iPAQ™ computer. As the standard operation is quite straight forward, the following discussions will focus on the "mounted" or remote operation.

The system is controlled and monitored from custom software on the Compaq iPAQ™ PocketPC™ provided with the system. The software is typically only used to drive the Pan/Tilt unit to the desired direction, and to monitor the signal. However, to support unanticipated hardware changes in the future, a setup capability was provided. The main operating menu is the control menu which is shown in Figure 43.

2.3.4.2 Delivery to Law Enforcement for Evaluation

The modified radar flashlight was delivered to the US Army for evaluation for several months and has since been returned to GTRI for refurbishment. GTRI is presently prepared to deliver the unit to AFRL as soon as the particulars of delivery can be defined.

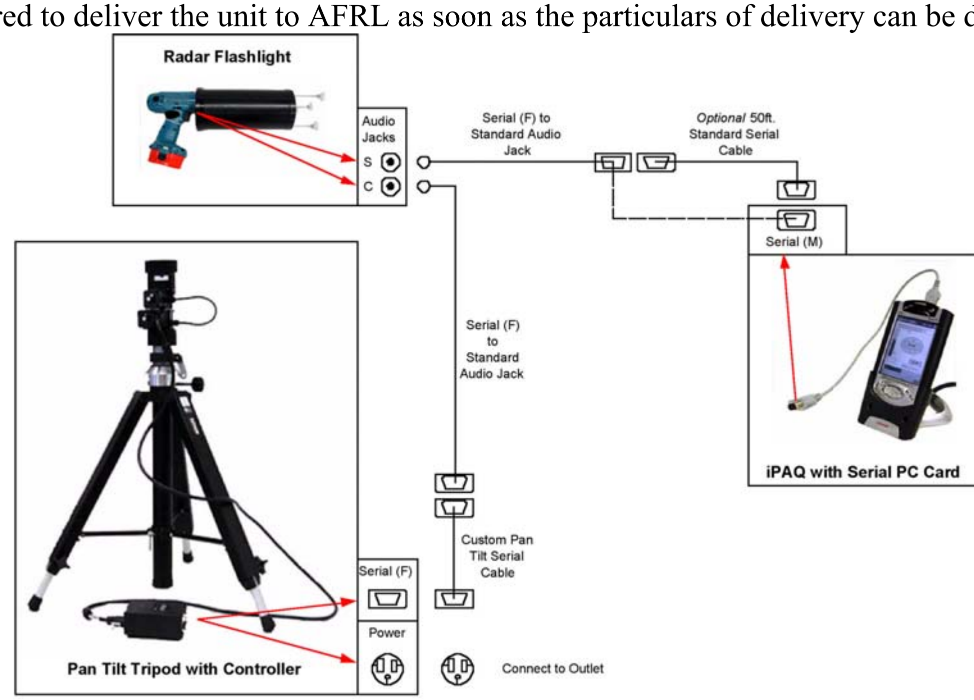

Figure 42. Configuration diagram of GTRI Radar Flashlight ™ mounted on a Tripod along with remote Palm Pilot™ display.

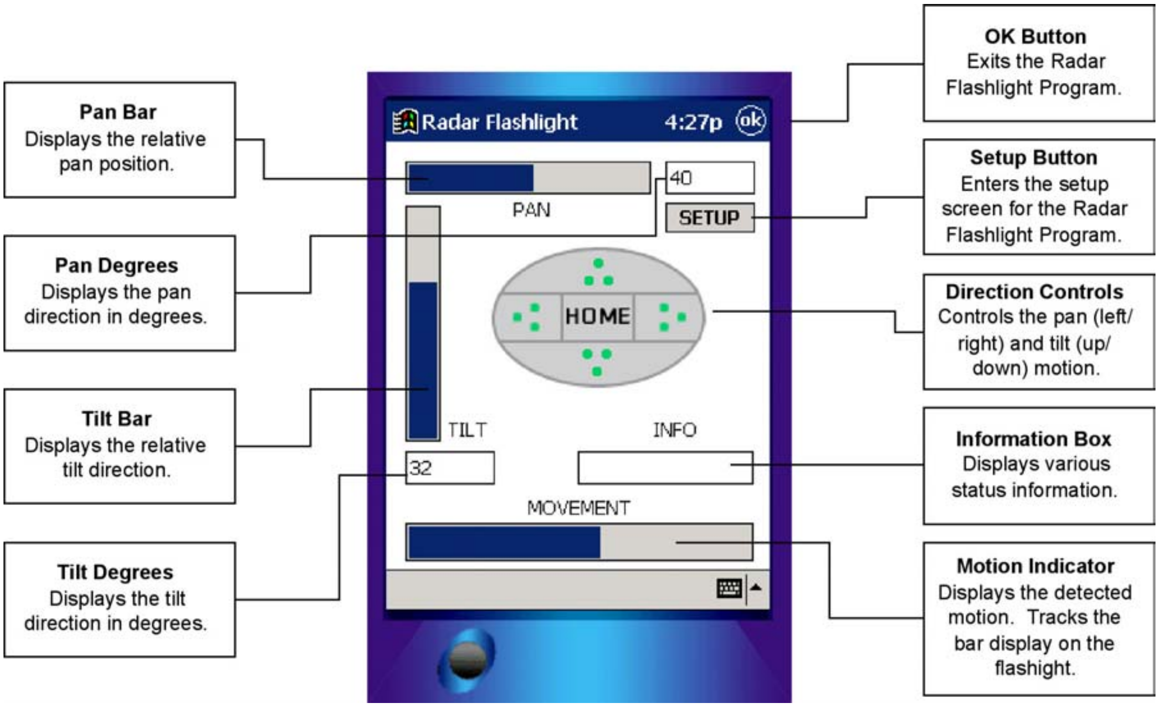

Figure 43. iPAQ PocketPC Flashlight control software main menu.

SECTION 3 POINT OF CONTACT FOR NIJ'S CRITICAL INCIDENTS PROGRAM

3.1 Support to Joint Program Steering Group of NIJ/OST

During the period of the contract, Mr. John Stedman supported Dr. Pete Nacci in ON-SITE management and assessment support for a number of JPSG programs including:

- Personal alarm monitor;
- Escape mask;
- WMATA Protect Project;
- Emergency Preparedness and Incident Command System (EPICS);
- Chemical facility vulnerability project;
- WMD equipment compendium;
- WMD threat assessment;
- Force Protection Equipment Demonstration (FPED III);
- District of Columbia Office of Emergency Management project;
- Incident Management Software Test Bed Project;
- Automated Regional Criminal Justice Information System (ARJIS);
- ARJIS/San Diego FBI JTTF Information Sharing Project;
- Law Enforcement and Corrections Tactics Simulation System (LECATS).

3.1.1 Personal Alarm Monitor

The personal alarm monitor is one of the highest priority technology needs of law enforcement responders in combating terrorism. The device will allow timely warning of exposure to a wide variety of chemical and biological hazards. RADC represented the JPSG in collaboration with the Technical Support Working Group (TSWG) in monitoring Arthur d. Little of Cambridge, Massachusetts, the developer of the device. The initial priority is the detection of anthrax although other agents will be detectable eventually. Ina laboratory environment ADL demonstrated an ability to detect nerve agents in less than lethal concentrations in sufficient time to allow for preventive measures. It is now in the process of developing a prototype design that will alert the wearer to exposure through an audible or vibratory stimulus. An unspecified number of prototypes will be provided to the US Army Soldier and Chemical Biological Command (SBCCOM) for technical assessment in FY'03.

3.1.2 Escape Mask

RADC supported the JPSG in collaborating with the TSWG to develop a short duration protective mask that will protect first responders for enough time to exit a hazardous area, alert appropriate officials, and prevent others from entering a contaminated area. The requirements for the mask include: lightweight, low-cost, and easy carrying and donning with little or no advanced notice. TSWG issued a Broad Agency Announcement

solicitation for the escape mask and is expected to award a contract prior to the end of FY'02.

3.1.3 WMATA PROTECT

RADC, representing the JPSG, collaborated with the Washington Metropolitan Area Transit Authority (WMATA) and the Department of Energy to demonstrate the utility of chemical detection monitor in a subway environment. A unified approach is being taken to develop a capability for protection through the installation of a prototype real-time early warning chemical detection and alarm system. The Program for Response Options and Technology Enhancements for Chemical/Biological Terrorism (PROTECT) will integrate technologies into a unified approach for installing a prototype real-time early warning sensor. The system will incorporate a CB Emergency Management Information System (CB_EMIS) to increase the speed of evacuation with emergency alarms, video coverage, announcements, and equipment shut-down. The system was developed in FY'00, tested in FY'01, and a Station Test Exercise was conducted in FY'02.

RADC worked with the Washington Metropolitan Transit Authority Police Department to insure their participation in testing chemical sensors in the subway system and providing a site for simulation training.

RADC worked with the Washington, DC, Emergency Management Office to identify the lessons learned during simulations of emergencies and to develop simulations for training.

RADC worked with the San Diego, CA Police department to ensure their participation in providing a site for emergency responder simulation training.

RADC recruited law enforcement practitioners to serve as peer reviewers for solicitations submitted to the NIJ and briefed them on ongoing prototype sensor developments.

3.1.4 Emergency Preparedness and Incident Command System (EPICS)

RADC supported the NIJ in working with the TRADOC Analysis Center at The White Sands Missile Range, New Mexico, to demonstrate a capability to use the Emergency Prepare3dness and Incident Command Simulation (EPICS) to provide a high-resolution simulation to local, state, and federal agencies involved in emergency planning and management. The simulation is to be used for training of operations command and control personnel. Three scenarios are being developed: a chemical agent release in a subway, a disturbance in a correctional facility, and an attack on a public school. The school shooting scenario was field tested in San Diego in March 2001. The correctional facility scenario was field tested at the Southern New Mexico Correctional Facility in April 2001.

3.1.5 Chemical Facility Vulnerability Project (CFVA)

RADC served as a representative of the NIJ to monitor the CFVA project being conducted by Sandia Laboratories under the direction of OS&T. This project is to develop, test, and validate a prototype VA methodology for assessing the security of chemical facilities against terrorist attacks.

The CFVA team held discussions with over 20 organizations and visited four chemical facility sites in order to develop the VA methodology. A CFVA website has been developed to provide a means for the public to provide inputs. A report was made to Congress at the end of 2001.

3.1.6 WMD Threat Assessment

RADC represented the JPSG in monitoring a study to define the chemical and biological agents that first responders are most likely to encounter in a terrorist attack. The Office of Law Enforcement Standards (LES) is coordinated the development of a national suite of standards for chemical, biological, radiological, and nuclear detection to enable equipment manufacturers to fabricate equipment that meets responder requirements. A "Guide for the Selection of Chemical Agent and Toxic Industrial Material Detection Equipment for Emergency First Responders," was published in June 2000. Four additional guides are in draft and should be published in the near future.

3.1.7 Force Protection Equipment Demonstration

RADC supported the Force Protection Equipment Demonstration III (FPED III) sponsored by the NIJ, the Office of the Under Secretary of Defense for Acquisition and Technology (OUSDA&T), the Joint Non-Lethal Weapons Directorate, and the DOE. The meeting was held at the Quantico Marine corps Base, Virginia, in May 2001, and showcased blast protective barrier systems and windows, personal protective equipment, explosive ordinance disposal equipment, unattended ground sensors, ballistics mitigation equipment, night vision devices, first-responder equipment, unmanned aerial vehicles, and waterside security equipment. Blast/ballistics, non-lethal, night vision, and biometrics were highlighted.

3.1.8 Law Enforcement and Corrections Tactics Simulation System (LECATS)

RADC supported the NIJ's funding of the South Carolina Research Authority to analyze the current Department of Defense (DOD) Joint Conflict and Tactics Simulation System (JCATS) to determine its most effective application to the law enforcement community. A modified JCATS to be known as the Law Enforcement-Conflict and Tactics Simulation System (LECATS) may allow the development of increasingly complex scenarios for personnel training using computer models of real facilities.

3.2 JPSG Liaison to the National Domestic Preparedness Office (NDPO) and the Office of State and Local Domestic Preparedness Services (OSLDPS)

RADC served on-site at the OS&T as the point of contact between the NIJ/OS&T and the National Domestic Preparedness Office and the Office of State and Local Domestic Preparedness Services. RADC also represented the NIJ on the Interagency Board (IAB) and various Technical Support Working groups (TSWGS).

3.3 JPSG Liaison with National Institute of Standards

RADC represented the JSPG on the Standards Coordinating Committee of the IAB. We coordinated the publication and distribution of the first series of guides for the selection of detection, decontamination, communication, personnel protection, and medical equipment for use during a terrorist incident. The Strategic Plan for Developing Chemical, Biological, and Nuclear (BRN) Equipment Standards was drafted and approved.

A Memorandum of Understanding (MOU) has been developed between NIST, NIOSH, and SBCCOM for standards to be developed for a respirator. As a first step, NIST/OLES published the NIJ "Guide for the "Selection of Chemical Agent and Toxic Industrial Material Detection Equipment for Emergency First Responders," in June 2000. NIJ guides for Biological agent detection, decontamination, communication, and personnel detection equipment are due to be disseminated in late FY'01.

RADC personnel directed The John Hopkins University Applied Physics Laboratory (JHU/APL) in an assessment of communications technologies during the TOPOFF 2000 terrorism exercises. The goal is to develop a TRP for the NIJ/OS&T. RADC gathered information from state and local first responders concerning counter-terrorism technology needs and experiences.

3.4 Consulting on Further Developments and Improvements to Counter-Terrorism Technologies

RADC participated in NIJ/OS&T program reviews of counter-terrorism technology research and development efforts funded by the NIJ/OS&T and provided recommendations based on other work. RADC also tested three concealed weapon detection or through-the-wall sensors. The results were provided to the NIJ along with recommendations as to further efforts.

SECTION 4 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

4.1 Summary

The following tasks were performed under this contract:

1. (SOW 4.1) Provide an expert on counter-terrorism to serve as technical point of contact for the NIJ for counter-terrorism technologies. Mr. John Stedman of RADC provided on-site support to the NIJ during the effort. These efforts are discussed in section 3.

1.1 (SOW 4.1.1) In conjunction with law enforcement agencies participate in prototype testing, demonstration, and evaluation of counter terrorism technologies. Mr. John Stedman served on NIJ/OS&T program reviews of counter-terrorism technology research and development efforts funded by the NIJ/OS&T. Three prototype CWD/TWS sensors were evaluated by RADC under this program. The details of these evaluations are discussed in Section 2.

1.2 (SOW 4.1.2) Develop and implement assessment plans for prototype testing of counter-terrorism technologies. Two test plans were prepared and submitted prior to the testing of prototype CWD/TWS sensors which are discussed in Section 2. Also, Mr. John Stedman provided input into test planning for First Responder sensors and scenarios which is discussed in Section 3.

1.3 (SOW 4.1.3) Gather assessment information on counter-terrorism technologies. Mr. Mr. John Stedman served in the role of gathering information from local, state, and federal law enforcement authorities on problems and concerns relative to chemical, biological, radiological, and nuclear detection technologies. This effort is discussed in Section 3.

1.4 (SOW 4.1.4) Recommend further development and improvements to the technologies. Mr. John Stedman served on numerous panels which reviewed counter-terrorism technologies which is discussed in Section 3. Recommendations were provided for the three prototype sensors evaluated as to needed improvements and desired further development which are discussed in Section 2.

1.5 (SOW 4.1.5) Provide a point of contact for the NIJ's critical incidents program. Mr. John Stedman served as the point of contact between the NIJ and the critical incidents program. This is discussed in Section 3.

1.5.1 (SOW 4.1.5.1) Identify and prioritize critical incident technology needs. Mr. John Stedman served in this capacity for the critical incidents program. This is discussed in Section 3.

1.5.2 (SOW 4.1.5.2) Identify the operational context within which these technologies will be employed. Mr. John Stedman served as the point of contact between the NIJ and critical incidents program in numerous groups which performed these tasks. This is discussed in Section 3.

1.5.3 (SOW 4.1.5.3) Identify ongoing research and development efforts which are applicable to the critical incidents program. Mr. John Stedman served as the point of contact between the NIJ and critical incidents program in numerous groups which performed these tasks. This is discussed in Section 3.

1.5.4 (SOW 4.1.5.4) Develop critical incidents technology standards and testing methodologies. Mr. John Stedman served as the point of contact between the NIJ and critical incidents program in numerous groups which performed these tasks. This is discussed in Section 3.

1.6 (SOW 4.1.6) Test and Evaluate CWD prototype sensor systems provided by the NIJ and AFRL at the Rome site. Three prototype sensors were evaluated under the program. Each test is discussed in Section 2.

1.6.1 (SOW 4.1.6.1) Design tests and conduct evaluations to determine the probability of detection of concealed weapons and the probability of false detection for each prototype. Three prototype sensors were evaluated under the program. Each test is discussed in Section 2. The probability of detection and probability of false detection was determined for two of the sensors.

1.6.2 (SOW 4.1.6.2) Analyze and test the ability of the prototype sensors to detect concealed weapons under varying environmental conditions. Three prototype sensors were evaluated under the program. Each test is discussed in Section 2, and involved testing under varying environmental conditions.

1.6.3 (SOW 4.1.6.3) Utilize law enforcement personnel to evaluate the utility of each prototype in terms of ease-of-use of the output display, portability, and applicability to various law enforcement problems. Information on prototype sensors under development was provided to law enforcement personnel by RADC for use in evaluating procurements for the NIJ. Also, the GTRI Radar Flashlight™ was provided to the US Army for evaluation as a urban warfare sensor.

1.6.4 (SOW 4.1.6.4) Modify the existing Georgia Tech Research Institute Radar Flashlight™ prototype sensor to provide for set-back operation on a tripod with a remote display. A unit of the modified sensor is to be provided to AFRL/NIJ for testing and evaluation. The unit has been developed by the Georgia Tech Research Institute, was loaned to the US Army for evaluation, and is currently awaiting disposition orders from AFRL/NIJ.

1.7 (SOW 4.7) Reports and Documentation

The following reports were submitted under the contract:

1. Quarterly status reports;

2. Test Plans:
   Time Domain prototype sensor evaluation;
   JAYCOR prototype sensor evaluation;

3. Technical Reports:
   Time Domain prototype sensor test and evaluation;
   JAYCOR prototype sensor test and evaluation;
   Radar Flashlight Users Manual;
   Final Technical Report;

4. Briefings:
   Time Domain Test Summary;
   JAYCOR Test Summary;

4.2 Conclusions

Support was provided on-site at the NIJ in the management of various coordination efforts. Continued support in this area does not appear to be warranted at this time.

Three prototype sensors were either demonstrated or tested under this effort. Two of the three sensors, the Trex Enterprises radiometer and the Time Domain radar, worked reasonably well and should continue development. The third sensor, the JAYCOR acoustic radar did not perform well enough in the evaluation test to recommend further work unless an alternate approach can be devised to improve performance such as a different frequency, etc. The details of all three sensors are discussed in Section 3.

4.3 Recommendations

AFRL/NIJ continues to develop a number of prototype sensors for law enforcement support. Included in the set are both concealed weapon detection and through-the-wall surveillance sensors. RADC possesses expertise in evaluating these types of sensors and can provide an independent evaluation of the performance and any needed improvements. The following specific recommendations are offered:

- Improved versions of the Trex Enterprises and Time Domain sensors, currently under development should be evaluated;
- Other CWD/TWS sensors, currently under development, should be evaluated once they reach the point of being brass boards;

- Sensors that should be evaluated include: the Akela radar, the Lockheed-Martin radiometer, the Raytheon radar, and any other IR, RF, or MMW sensors under development;
- Since technology changes with time, a periodic Request For Information (RFI) in the area of CWD/TWS should be published to locate any new promising technologies.

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